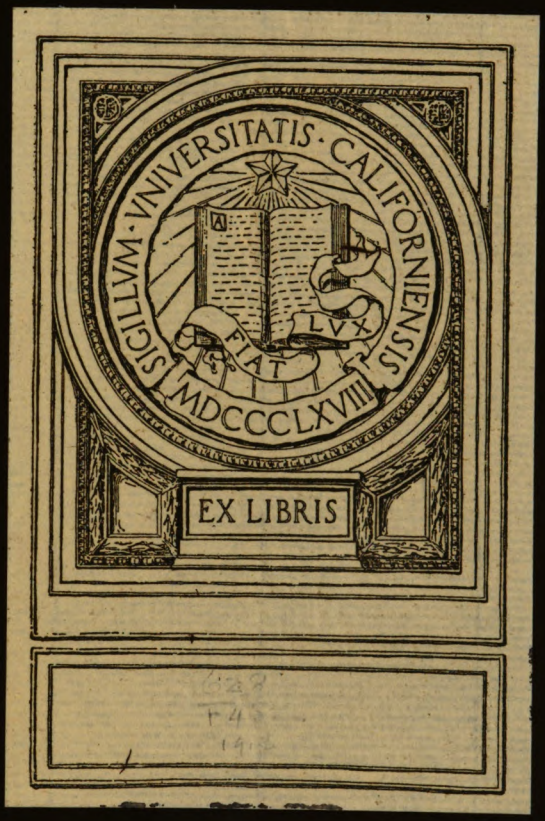

A TEXT-BOOK

ON

FIELD FORTIFICATION

BY

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THIRD EDITION, ENTIRELY REWRITTEN

FIRST THOUSAND

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"Field-works will hereafter play an important part in wars, because they enable a minor force to hold a superior one in check for a time, and time is a most valuable element in all wars."

—Memoirs of Gen. W. T. Sherman.

PREFACE TO FIRST EDITION

In preparing this text-book for use in the course of instruction in field fortification at the United States Military Academy, the aim of the author has been to state briefly and clearly the principles of the art, and to illustrate them as far as possible by examples drawn from the experiences of field armies in recent wars; to show the relation which field fortification bears to the tactics of the battle-field and the strategy of campaigns; to modify the types of construction employed in the course to conform to the conditions imposed by modern firearms; and to omit the description of methods and constructions considered more or less obsolete.

Since the details of field fortification, like those of other engineering works, are susceptible of indefinite variation, the illustrations shown in the plates must be considered simply as types of construction, not to be slavishly followed, but modified to conform to the varying conditions of site and service.

To the chapters on field fortification proper have been added a few others, covering briefly the simple engineering operations of an army in the field. The subject of siege-works has been omitted from the present edition, as this subject is taught at the Academy in connection with military mining.

In this work the author has been aided by the suggestions of the officers on duty in his department, one of whom, Captain Chester Harding, Corps of Engineers, prepared many of the drawings.

G. J. F.

West Point, N. Y., Nov. 21, 1900.

PREFACE TO THIRD EDITION

SINCE this text-book was first written in 1899, two great wars have been fought in which the principles and types of field fortifications have been thoroughly tested.

In our own service, new Field Service Regulations and new Infantry Drill Regulations have been introduced based on the lessons of these wars.

The Field Fortification has been rewritten to bring it into harmony with these new regulations.

G. J. F.

October, 1912.

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FIELD FORTIFICATION

CHAPTER I

THE ART OF FORTIFICATION AND THE EFFECT OF THE DEVELOPMENT OF FIREARMS UPON FIELD FORTIFICATION

A *military position* is any site which is, or may be, occupied by troops for the purpose of receiving or making an attack.

Fortification is the art of increasing by engineering devices the fighting power of troops that occupy a position.

The relation of fortification to the other great divisions of the art of warfare, strategy and tactics, may be stated as follows: *strategy* determines the location of the position which must conform to the general plan of campaign; *tactics* determines the best disposition of the troops upon the position for offense or defense; *fortification* improves the natural features of the position so as to increase the chances of tactical success.

These three divisions of the art of war are mutually dependent; the best results can be obtained only by a skilful combination of all.

For purposes of study, the art of fortification is divided into *permanent fortification* and *field fortification.*

Permanent fortification deals with the defensive works constructed by a state to secure permanent possession of

important strategic positions within its territory. Important naval and commercial harbors, political capitals, bridges over great rivers, important passes in mountainous regions, and great railway centers are positions ordinarily protected by permanent fortifications.

The works are usually constructed during time of peace, when the military engineer has at his command all the resources of the state. They are made sufficiently strong to resist all ordinary attacks of a field army.

A position protected by permanent fortifications and properly garrisoned should yield only after a protracted siege.

Field fortification deals with all defensive works of a temporary character which are constructed during a war, and which will lose their military value at its close. The works may be constructed by the field army with the tools which form part of its equipment, or by the reserve army utilizing all the resources of labor and material afforded by the surrounding country.

Field fortification may be divided into:

1. *Hasty intrenchment;*
2. *Deliberate, semi-permanent* or *provisional intrenchment;*
3. *Siege-works.*

Hasty intrenchment deals with all engineering devices resorted to by troops about to engage an enemy to increase or prolong their fighting power. The term is usually confined to works that can be executed in *hours* or *days* with the intrenching tools of an army and the materials either in stock or on the site.

Deliberate, semi-permanent or *provisional fortification* deals with fortifications constructed by a field army when there is a lull in field operations covering a period of *weeks* or *months*, and those constructed by reserve troops and civilian labor in rear of the curtain formed by the field army.

They differ from hasty intrenchments in being more carefully planned and executed. All the resources of the surrounding country are drawn on for their construction.

Intrenched battle-fields to which the field army may retire, military depots, lines of communication and supply, lines of retreat, and temporary strategic points are thus fortified.

Positions permanently fortified are strengthened in time of war by deliberately constructed field works.

Siege-works comprise all the engineering devices resorted to by the besieger and besieged in the attack and defense of a strong fortification.

In the application of the art of fortification the three classes of field fortification frequently merge into one another.

An army occupying a good strategic position may hastily intrench itself for the simple purpose of fighting a defensive battle; successful in the battle but unable to take the offensive, it may gradually strengthen its position until it has all the characteristics of a position deliberately fortified, and the assailant may find himself compelled to resort to a blockade or to a siege to secure its capture.

The positions around Petersburg, Virginia, occupied by the Confederate and Union armies from June, 1864, to April, 1865, and those around Plevna occupied by the Turkish and Russian armies from July to December, 1877, were thus fortified.

However they may differ in construction, the *object* of each fortification is:

1. To increase the destructive effect of the fire of the troops covered by the fortification and to facilitate their free movement upon the field of battle.

2. To decrease the destructive effect of the fire of the attacking troops and to interfere with their free movement.

To secure these objects the natural features of the position are modified so as to secure:

1. An unobstructed field of fire in front of the line of defense.

2. A shield which will protect the defender from the assailant's fire, or a screen which will conceal him from the assailant's view.

3. An obstacle by which the advance of the assailant is retarded.

4. Easy communications for tactical movements of the defender.

5. Obstructed communications for the movements of the assailant.

Effect of the Development of Firearms. From the middle of the sixteenth century until 1840, the infantry of the line was armed with a *flint-lock, smooth-bore, muzzle-loading musket.*

It was uncertain in action, particularly in wet weather; its effective range did not exceed 250 yards; and its rapidity of fire was limited to *one and one-half shots per minute.* Not being provided with adjustable sights, it was only fairly accurate up to the point-blank range, which was about 100 yards. In our own service the *percussion-lock musket* replaced the *flint-lock musket* in 1842 and was in use until 1855.

During the long era of the smooth-bore musket the *zone of aimed-fire* in front of an infantry line was only 100 to 160 yards wide; it could be crossed by the attacking force in less than *two minutes,* during which time the defenders could fire but two volleys.

The only kind of field fortification which was of any value to the defender was one composed of a *strong obstacle,* in the rear of which was some form of *shelter* for a line of troops.

As such works were difficult to construct, earthen field fortifications were rarely employed upon battle-fields; the defenders sought to replace them by occupying *villages, chateaux,* and *farms,* whose house and enclosure walls, loop-holed for defense, formed both the shelter and the obstacle.

When a position was deliberately occupied, *strong redouts* and *obstacles* were sometimes constructed.

All field fortifications were constructed by military engineers; they were employed not so much in battle-field intrenchment, as in the attack and defense of walled cities and in the protection of *encampments, bases* and *lines of communication.*

In 1855 in our service, the smooth-bore musket was replaced by a *percussion-lock, muzzle-loading rifle;* it was sighted to 500 yards, and was as accurate at that range as the smooth-bore had been at 100 yards.

By this change the zone of aimed-fire was increased to four times its previous width, and it became more difficult to cross. This was the weapon employed in the *Italian War* of 1859 and in our *Civil War,* 1861–1865.

The lessons of this latter war were briefly, that troops could not remain stationary without cover within the effective range of infantry fire; and that a well-intrenched line, occupied by two ranks of well-seasoned infantry, could not be taken by frontal assault.

These lessons were only gradually learned, but towards the close of the war the infantry of both armies were supplied with intrenching tools carried in wagons, and these tools were freely used whenever an engagement was imminent.

As the infantry firearm was a muzzle-loader, whose rapidity of fire did not exceed that of the smooth-bore musket, the shelters where practicable were protected by obstacles.

In 1869 in our service, the muzzle-loader was replaced by a *breech-loading rifle,* which was sighted to 1300 yards and with which *twelve shots* could be fired in one minute. This weapon increased both the width of the zone of aimed-fire, and the rapidity of fire over that zone.

Two great wars were fought with similar rifles, the *Franco-German* (1870–1871) and the *Russo-Turkish* (1877–1878). The effect of the new rifle in these wars was so

great, that it caused not only a revolution in infantry tactics, but also led to the introduction of instruction in the art of hasty intrenchment in the infantry of all great armies.

In order that the soldier might never be separated from his intrenching tools, small portable tools were issued to all foot troops. Obstacles lost some of their importance, as the fire became so intense that it was almost impossible to approach an intrenchment in daylight over an unobstructed foreground.

About ten years after the Russo-Turkish War, in our own army in 1892, the simple breech-loader was replaced by a *small-caliber magazine-rifle*, sighted to 2000 or more yards.

The new rifle has a high initial velocity and consequently a flat trajectory, which increases the chances of a hit at all battle ranges. The rapidity of infantry fire has increased to *twenty shots* per minute.

The introduction of this weapon again increased the width of the zone of aimed-fire and extended the zone in which troops must secure cover. No troops can remain stationary *in daylight* without cover within the limits of its accurate fire.

The introduction of the high-velocity magazine rifle led to the development of *night attacks*, which were employed occasionally in the *British-Boer War* (1899–1902) and almost continuously in the *Russo-Japanese War* (1904-1905). Night attacks made the employment of obstacles again necessary in the defense of fortified positions.

With the small-caliber magazine rifle came the use of *smokeless powder*. While black powder was the explosive used, it was useless to attempt to conceal the trenches of the defense, since they were certain to be exposed when the first volley was fired from them.

After the introduction of smokeless powder, it was found highly advantageous to make the trenches as inconspicuous as possible and thus conceal them from the

attacker's infantry and artillery. The importance of this invisibility was first demonstrated in the *British-Boer War.*

In the defense of contracted areas the defender has been greatly strengthened by the addition of *machine-guns* now attached to infantry units in all armies.

While the infantry arm was being developed from a *smooth-bore* to a *magazine-rifle*, the *field-gun* was also undergoing corresponding changes, becoming in succession, a *muzzle-loading rifle*, a *breech-loading rifle* and a *rapid-fire gun.*

The projectiles were in order of development, *solid shot, shell, shrapnel,* and *torpedo* or *high-explosive* shell.

With the increase in the range of artillery, *range finders* and *accurate sighting apparatus* for *direct* and *indirect fire* were devised.

The effect of these changes has been to increase the range and effect of field-gun fire to such an extent that the attacking infantry must deploy at a great distance from the defensive works and approach in small columns.

The effect of the artillery of the attack has also been greatly increased by the *curved* and *high-angle fire* of *howitzers* and *mortars* which have been added to the artillery of field armies. Only shelters with strong roofs will protect troops from the shrapnel or torpedo-shell fire of these guns.

Ranges of Modern Arms. In the Field Service Regulations the ranges of modern firearms are divided as follows:

Range.	Rifle Yards.	L. F. Artillery Yards.	H. F. Artillery Yards.
Close	under 600	under 2500	under 2500
Effective	600 to 1200	2500 to 3500	2500 to 4000
Long	1200 to 2000	3500 to 4500	4000 to 5000
Distant	over 2000	over 4500	over 5500

Infantry Fire. In the Russo-Japanese War, the Russian infantry in defense usually opened fire at 1200 yards,

but the Japanese suffered few casualties beyond 800 yards. The Japanese in the attack began fire at about 1000 yards.

It may therefore be assumed that infantry formations that can cross the *distant* and *long range* infantry zones under artillery fire will not, while in those zones, offer a target worthy of infantry fire.

Having reached the outer limit of *effective infantry fire*, 1200 yards, experience of the last two wars indicates that the attacking infantry will endeavor to cross the *effective* and *close* range zones in the following manner:

By advancing small units in succession it will first establish a strong infantry firing line under natural or artificial cover near the outer limit of the close-range zone, and then by infantry and artillery fire so overwhelm the defender that an infantry assault may be made from this advanced position by daylight or a new line may be established still nearer the defender's line.

If the defender indicates by his return fire that a daylight advance from this first line is not practicable, the attacking infantry will work forward from this position at night.

Artillery Fire. The artillery fire of the defense will prevent movement of large bodies of the attacking troops over open unconcealed ground within the distant and long-range zones and compel the deployment into small columns at the outer edge of its effective zone.

In advancing from 3500 to 1200 yards the attacking infantry will suffer mainly from the defender's artillery fire, and the losses due to this fire will increase as the attacking troops approach the line of defense.

In open terrain to avoid this fire, the attacking infantry may cross this zone at night or when the conditions of the weather render it invisible to the defender's artillery.

When the attacking troops intrench themselves within the effective infantry range of the defensive line, the defender will employ high-angle fire to dislodge them.

The artillery fire of the attack will attempt to silence

the batteries of the defense, particularly those that employ direct fire, and will attempt to produce a moral effect on the infantry of the defense by shrapnel, torpedo shells, and high-angle fire.

In the last stages of the attack, the batteries of the attack search the ground in rear of the defender's line to prevent the movement of reserves.

The British-Boer and the Russo-Japanese wars taught the lesson that infantry troops in deep trenches need have no fear of the shrapnel and shell fire of field guns; they can be reached only by high-angle fire.

CHAPTER II

FIRE, COVER AND COMMUNICATING TRENCHES

"Infantry charged with a resisting mission should intrench itself whenever there is a likelihood that cover constructed will be of use." —I. D. R.*

THE intrenchments that are ordinarily constructed by infantry to comply with the above tactical requirements are *fire, cover* and *communicating trenches.*

Fire Trenches.—The fire trenches are those occupied by the firing line of the infantry—the main line of defense.

"Fire trenches should be placed and constructed so as to give a good field of fire and to give the troops protection behind a vertical wall, preferably with some head or overhead cover."—I. D. R.

"A profile should be selected which will permit the fire to *sweep the foreground, require the minimum of time and labor,* and *permit the best concealment.* No fixed type can be prescribed. The type must be selected with due regard to the terrain, the enemy, time, tools, materials, soil, etc."—I. D. R.

"Fire effect is the first consideration."—I. D.R.

Profile. A *profile* is any section of a fortification made by a vertical plane perpendicular to the principal lines of the work; plate I, Fig. 9, is the profile of one of the fire trenches given in the *Field Service Regulations.*

The *elevation* of any point of the profile above the *plane of reference,* or the *depression* of any point below that plane, is represented by *figures preceded by the signs* + *or* −, according to the method of one-plane descriptive geometry. These figures are called the *references* of the

* Infantry Drill Regulations.

points or lines to which they belong. The *plane of site* is usually the plane of reference.

Nomenclature of Profiles. In Plate I, Fig. 9, the broken line *A, B, C, . . . K* is the profile of a fire trench in which *AK* is the *plane of site.*

The embankment above the plane of site is the *parapet;* the excavation below the plane of site is the *trench.*

The nomenclature of the surfaces and lines of the parapet and trench is as follows:

AB is the *foreground.*

BC is the *superior slope* of the parapet.

C is the *interior crest,* or *crest* of the parapet.

DE is the *elbow rest.*

EF is the *interior slope* of the fire trench.

FG is the *banquette,* or *firing step.*

GH is the *banquette slope.*

The *height* of the parapet is the vertical distance of the crest above the plane of site; its *command* over any point to the exterior is its height above such point.

A fire trench should permit troops to fire in a standing position. The requisites of a fire trench are:

1. A *bullet-proof parapet of minimum height.*
2. An *elbow-rest.*
3. A *steep interior slope.*

A *bullet-proof parapet* is one whose thickness at the crest is greater than the penetration of a rifle bullet given in the *table of penetrations* in the Appendix B. For ordinary earth the thickness should be *three feet.* This thickness is also proof against fragments of shell or shrapnel.

To resist single direct shots of field guns and field howitzers, a thickness of from 6.5 to 10 feet is required. (Appendix B).

The *concealment* of a fire trench is so important that its parapet should be as low as is consistent with a proper command of the foreground and the superior slope should blend with the foreground. If the enemy cannot locate

a fire trench, he cannot train his guns upon it, nor can he deploy his infantry to attack it in the best manner.

"Every effort had evidently been made to provide concealment from view, the works themselves, whether fire trenches or redouts, having a low command of only 18 inches, combined with a suitable background, which would prevent heads from showing up against the skyline, this background being frequently made up to the height required to fulfill this object." B. O. R., vol. 2, p. 634. (Description of Japanese trenches at close of war.)*

"The most striking characteristic of the later Russian defenses was undoubtedly *concealment*. Every care was taken to have as little showing above the ground as possible, and, whenever it could be done without showing up the position of the works, the excavated earth was not used in any way as a parapet, but was scattered over the ground if possible to the rear."—B. O. R., vol. 2, p. 637.*

"Where the excavated earth is easily removed, a fire trench *without parapet* may be the one best suited to the soil and other conditions affecting the choice of profile. The enemy's infantry as well as his artillery will generally have great difficulty in seeing this type of trench." —I. D. R.

"Best of all are the trenches adopted by the Siberian troops, of man's height *without a parapet.*

"Such trenches disappear from view at several hundred paces and present a safe shelter from artillery fire, because the entire mass of earth between the trench and the point of burst acts as a parapet. The narrow opening of the trench protects against shrapnel, and when the men sit on the banquette leaning against the interior slope they are almost entirely protected. For rifle bullets there is only a very insignificant target—the head of the soldier." †

Low command involves more time and labor than medium command and even in favorable soil it will often be found necessary to make the parapet higher than is absolutely necessary. If the soil is wet or rocky, excavation may be impossible, and high command will be necessary. The parapet should then be concealed by suitable coverings or screens such as weeds or brush *of the same color as the foreground.*

* British Officers' Reports of the Russo-Japanese War.
† Actual Experiences in Russo-Japanese War.—SOLOVIEV.

The *elbow-rest* should be 12 inches below the crest of the parapet and 1 to 1½ feet wide.

Besides serving as an elbow-rest, this berm serves as a shelf for extra ammunition.

A *steep interior slope* is important, as it enables the soldier to stand near enough to the parapet to rest his elbow upon it. This increases the effectiveness of his fire. A steep slope also gives the defenders, when sitting on the banquette, better cover from shell and shrapnel fragments than a more gradual one.

The interior slope should therefore be vertical or nearly so in stiff ground, and be revetted if possible in loose ground.

Fire Trench A. If time permits and the defense is to be obstinate, a fire trench of the type shown in Plate I, Figs. 7, 8 and 9, and given in F. S. R., should always be constructed.

This type of fire trench has been adopted by all modern armies.

The *banquette or firing step* is usually 4½ feet below the interior crest of the parapet, though this distance may be varied to accommodate the stature of the men. In the Japanese trenches in Manchuria it was less, and in the Russian trenches it was greater than 4½ feet.

The width of the banquette should be at least 1¼ feet as shown, and preferably 2 feet, if the banquette slope is not revetted, to allow for caving. When not using their rifles the defenders sit on the banquette with their backs to the parapet.

To the rear of the banquette is a lateral communicating trench whose bottom is *at least* 6 feet below the crest of the parapet, so that a man walking along the trench will be concealed from an enemy in front.

This lateral trench should be at least 2 feet and preferably 3 feet wide so as to allow a stretcher to be carried along the trench. In some of the Japanese trenches in Manchuria the passage was 5 feet wide.

Such of the excavated material as is not required in the parapet may be thrown to the rear of the trench, or employed in making headcover. If thrown to the rear it serves both as a background and as a shield against the fragments of a shell that bursts to the rear of the trench.

Fire Trench B. If time and labor do not permit the construction of fire trench *A*, the passage may be omitted and the bottom of the trench made to serve as a banquette. (Plate I, Figs. 1, 4, 5 and 6, from F. S. R.) When seeking cover from artillery fire, the men sit on the bottom, all facing one end of the trench.

This trench is considered only as the *preliminary step* in the construction of a trench with a banquette.

Fire trench *B* was the type of trench employed by the Russians in their field intrenchments up to the battle of *Liaoyang*. After that battle the fire trench *A* was constructed wherever possible.

Hasty Cover. The term hasty cover is employed in the Infantry Drill Regulations to describe the cover thrown up to protect men in a prone or a kneeling position.

The simplest hasty cover is that for troops lying down. Each man with his intrenching tool scoops out a shallow trench in which he can lie and throws up the material into a low mound, which conceals him from view and protects him from *infantry fire.*

A man in a prone position can fire over a mound *one foot high.* Plate I, Fig. 2, is a profile along the axis of the excavation.

"With the intrenching tool, troops can quickly throw up a low parapet about 3 feet thick, which will furnish considerable cover against rifle fire but scarcely any against shrapnel. Such cover is frequently of value to an attack that is temporarily unable to continue. In time, and particularly at night, it may be developed into a deep, fire, or cover trench."—I. D. R.

To secure better protection from *shell and shrapnel* fire, the cover may take the form shown in Plate I, Fig. 3,

in which troops secure protection by sitting in the bottom of the trench with their backs to the interior slope. By kneeling in the trench they can fire over the parapet, whose crest is 3 feet above the bottom of the trench.

For infantry on the defensive, hasty cover is only a *preliminary step* in the construction of deep trenches.

Traverses. A traverse is a mound of earth which is utilized to intercept infantry and artillery fire.

Traverses in Fire Trenches. If the line of a fire trench prolonged intersects a portion of the terrain that may be occupied by the enemy in the attack, provision must be made for protecting the men from fire which enfilades the trench. For this purpose traverses are provided. Traverses also localize the effects of shells which explode in a trench.

To be proof against rifle fire and the fragments of shell and shrapnel these traverses are 3 feet thick.

"Where the nature of the position makes it advisable to construct traverses at regular intervals, it is generally best to construct a section of trench for each squad with traverses between squads."—I. D. R.

This arrangement is shown in Plate II, Fig. 1. Traverses that are connected with the parapet, as those shown in this figure, are called *attached* traverses. The passage in rear of the traverse should admit of the passage of a stretcher.

If the front line of the traverse terminates in rear of the parapet and leaves a passage between the parapet and traverse, it is called a *detached* traverse.

In the Japanese defensive line north of Mukden in Manchuria the trench in rear of the banquette was wide. To protect the line from enfilade fire, detached traverses were constructed to protect the passage, and attached traverses were constructed to protect the defenders of the parapet.

"The main traverses were never more than 15 yards apart and in many cases considerably less, while smaller intermediate traverses were

often so close together as only to give room for three and sometimes only two men between them.

"The dimensions of the main traverses were—length 9 feet, thickness 5½ feet, height above crest 13 inches.

"It will be noticed that these traverses were constructed so as to leave room for men to stand between them and the parapet. The works were not, so far as one could see (the kaoliang was then at its highest) open to enfilade fire from any direction, but the undulating nature of the country rendered this provision a wise precaution."—B. O. R., vol. 2, pp. 630–631.

"Where necessary, the Russian trenches were traversed for protection against enfilade fire; both attached and detached traverses being employed."—KUHN, p. 109.*

Headcover. The foreign military observers have testified to the value of headcover in the Russo-Japanese War.

"Some form of headcover was shown to be necessary to give protection and confidence to troops when long exposed to shrapnel fire.

"The chief defect in the defenses [Russian, west of Mukden] seemed to be the absence of headcover, which compelled the defenders to expose their heads and shoulders each time they fired. This is probably another reason for the success of the Japanese, who make a practice of continuing their shrapnel fire until their attacking troops have actually reached the enemy's works, regardless of the losses they may cause their own infantry. The defenders are therefore prevented from using their rifles with the confidence which they would have if they were able to fire through loopholes. The result is that at the very moment when a steady and well-directed fire might probably cause such losses to the attacking troops as to make a further attempt impossible, the defenders are compelled to take cover from the Japanese shrapnel."—B. O. R., vol. 2, p. 214.

On the other hand, some officers who took part in that war oppose the construction of headcover before the enemy's infantry makes its appearance, since they make the trenches more conspicuous.

"Headcover, notches, and loopholes are of value to troops when firing, but many forms weaken and disclose the location of the parapet. Filled sandbags kept in the trench when the men are not firing may be thrown on the parapet to form notches or loopholes when the troops in

* Report of Maj. Joseph E. Kuhn, Corps of Engineers, U. S. Army.

the trench open fire, and concealment of the trench is no longer necessary or possible."—I. D. R.

A sandbag filled with gravel placed within an empty sandbag should be used for this purpose, as a single thickness of bag is easily ripped by a bullet.

Various devices may be employed to secure headcover, such as *notches, bonnets* and *loopholes.*

The parapet may be raised to a height of $5\frac{1}{2}$ or 6 feet above the banquette and a notch or groove made for each rifle.

A *bonnet* is a small traverse placed on the parapet between each two rifles. It gives the parapet a battlemented appearance.

The bonnets may be circular or square mounds, or may be shaped as in Plate II, Fig. 6.

"At Liaoyang and Haicheng the Japanese had little mounds of mud on the superior slope. In the absence of better material these mud mounds afforded a simple and fairly effective form of headcover."—KUHN, p. 112.

The amount of protection and the field of view and fire may be varied by varying the splay of the openings between consecutive bonnets.

A *loophole* is an aperture through which a rifle may be fired.

A long narrow loophole may be made by laying boards or poles on skids or bonnets so as to leave a space of 3 or 4 inches between the under side of the boards and the superior slope. The parapet is then raised to the proper height to give headcover by piling sod or sandbags on the boards. (Plate II, Fig. 4.) If the loophole roof projects back over the banquette, a *hooded loophole* is formed.

A rectangular loophole may be made between the bonnets with sandbags, sod, bricks or wooden funnel-shaped frames. (Plate II, Fig. 5.)

In siege works a vertical steel plate having a loophole is placed vertically between bonnets.

"When loopholes were used in field works, they were made most frequently of sandbags or sod. When available, brick and stone were also employed."—KUHN, p. 112.

If a field fortification cannot be concealed and is to be held to the last extremity it should be provided with headcover. Hooded loopholes were found to be the most effective type for daylight defense at Port Arthur. To repel night attacks, arrangements were made to fire *over* the parapet, as the loopholes obstructed the view.

Headscreens. If a parapet is not provided with headcover, its position is sure to be betrayed by the curiosity of the defenders who will raise their heads above the parapet to inspect the foreground. If a thin screen of brush is placed along the parapet this betrayal will be avoided. In the Russo-Japanese War kaoliang stalks (similar to large corn stalks), were used for this purpose.

Overhead Cover for Fire Trenches. A soldier sitting on the banquette of fire trench *A* is well protected from the *field-gun* fire of attacker.

For this reason and because of the difficulty of securing materials and of constructing proper overhead covers, these have been usually omitted from the fire trenches of positions occupied only for a short time.

"Overhead cover along the fire lines was not generally used in field works, although very common at Port Arthur. In a few cases where the lines were held for a long time in close proximity, as on the Shaho, overhead splinter-proofs were constructed."—KUHN, p. 113.

"Overhead cover was provided in a very few instances; for the most part there was neither headcover nor overhead cover of any sort provided." (Japanese line north of Mukden.) B. O. R., vol. 2, p. 631.

"Light overhead covers may serve as protection against shrapnel and are often used in field fortifications. They are made of thin poles 2 or 3 inches in diameter covered by two layers of sod. They can give no protection against shells.

"It must be admitted that overhead covers have many opponents:

"1st. They obstruct the firing lines.

"2d. They are not of much use, since they are easily destroyed by shells and their number (two or three per company) is too limited to give shelter to a large body of men, and there arises the question, who of the company shall occupy them.

"3d. It has been observed that it is pretty difficult to assume the offensive from behind cover."—SOLOVIEV.

It is evident that in the last quotation, Captain Soloviev refers to such overhead covers as may be made by throwing light roofs over the trench.

Overhead cover has, however, a real value in its moral effect on troops long exposed to a concentrated artillery fire and in the protection it gives from winds and rains. In open trenches, troops will suffer loss from the occasional shell or shrapnel which bursts at the right point, and their nerves are under tension due to these occasional shots.

In deliberate intrenchment, particularly in the organization of key-points, overhead covers should be provided. The covers should be under the parapet and should be made in short lengths.

Plate I, Fig. 6, shows a profile of such cover for fire trench *B*; overhead cover for fire trench *A* is shown in Plate II, Figs. 1, 2 and 3. The roof of the latter is made of planks or balks 12 feet long; these support the rear of the parapet, which is made of sod or sandbags. The recess under the parapet shelters a half-squad.

The rear of the cover may be closed by a movable, wooden, splinter-proof shield or by a canvas curtain.

Short lengths of cover are made, because it is impossible with ordinary field materials to make a roof proof against vertical fire (see Appendix *B*), and it is therefore desirable to localize the effect of a single shot.

Other forms of overhead cover for fire trenches employed in the Russian bridge-head at *Liaoyang*, are shown in Plate IV, Figs. 1 and 2.

An overhead cover is also called a *blindage*. If it resists vertical fire it is also called a *bombproof*; if it

resists only shrapnel and shell fragments it is called a *splinter-proof*. (For thickness see Appendix B.)

Breastworks. If the soil is of a character to preclude the excavation of a trench, a parapet of sandbags, logs, railroad rails, etc., may be substituted for it; this is usually called a *breastwork.*

If logs or rails are employed, and the soil permits it, two rows of posts are planted and the logs or rails are laid between them. Headcover is secured by leaving a horizontal slit in the breastwork. Plate III, Fig. 1. (For thickness see Appendix B.)

Masonry Walls. In the defense of villages and towns, masonry inclosure walls are often employed as substitutes for fire trenches. They have played an important part in European warfare.

Brick Walls. A brick wall one header thick will resist a single rifle shot, and a wall one and a half headers thick will resist an infantry attack. (See Appendix B.)

For the purpose of securing headcover, a wall may be crenelated or loopholed (Plate III, Figs. 2 and 3).

A *crenelated* wall is one in which vertical openings have been cut from the top of the wall to the desired elevation of the line of fire; these openings are about 3 inches wide.

If the wall is *thin*, a *loophole* is usually constructed by removing a brick from the face or back of the wall and breaking out the remainder; the loophole has its splay only in one direction and preferably to the rear. In *thick* walls the splay is from the interior of the wall in both directions.

The size of the loopholes must depend upon the desired field of fire; the smallest dimension is usually about 3 inches.

If a wall is 8 feet or more in height, Plate III, Figs. 2 and 3, it not only forms a good obstacle and screen, but also allows of the formation of two tiers of fire. If the two tiers are secured by means of crenelations and loopholes, the crenelations should be over the intervals between the

loopholes so as not to unduly weaken the wall. Loopholes and crenelations indicate to the enemy that the wall is prepared for defense and may sometimes be constructed simply to deceive him.

Brick walls which resist rifle fire will also resist the penetration of fragments of shell and shrapnel, but, unless 3 feet thick, they will not resist penetration of an unexploded shell or shrapnel. Where exposed to artillery fire, a thin brick wall should be used only as a revetment for the interior slope of an earthen parapet.

Stone Walls. Stone walls offer greater resistance to fire than brick walls, but they cannot be so easily loopholed.

Stone inclosure walls were frequently used for breastworks in our Civil War.

Embankments. An embankment, such as a causeway, may be converted into a defensive line (Plate II, Fig. 8) by excavating a fire trench in it, or the entire embankment may be used as a parapet by constructing a banquette in its rear. The former method is the better, as the foreground can be more thoroughly swept.

The principal objection to a causeway is that it usually presents a conspicuous target to the enemy's artillery.

Excavations. If the foreground is clear, deep sunken roads or similar excavations form excellent fire trenches. To prepare an excavation for defense it is only necessary to construct a banquette in the face of the slope on the side toward the enemy (Plate II, Fig. 9).

Excavations are particularly valuable as defensive positions, because they afford no visible target to the assailant's artillery, and give to the assailant's infantry no indication of their extent or the numbers of the defending force.

Sunken roads were of conspicuous value on the battlefields of *Antietam*, *Fredericksburg* and *Shiloh* in the Civil War. A stone quarry played an important part in the battle of *Gravelotte* in the Franco-German War.

Cover Trenches. Cover trenches are the trenches which are constructed for the supports and reserves of a firing line to conceal them and to protect them from artillery fire.

"The cover trench is simple and rectangular in profile. Concealment is indispensable. It is generally concealed by the contour of the ground or by natural features, but to guard against hostile searching fire overhead cover is frequently advisable.

"Cover trenches should be made as comfortable as possible. It will often be advisable to make them extensive enough to provide cooking and resting facilities for the garrison of the corresponding fire trenches." —I. D. R.

An open cover trench may be either fire trench *A* or *B*, without the elbow rest, or it may be like Plate IV, Fig. 6.

Overhead cover is more common in the cover than in the fire trenches. If the position is to be occupied for some time, protection from the weather is essential; if the enemy has field howitzers, bomb-proofs are very desirable.

The overhead cover may take the form of a recess in the front slope of the trench, as in the fire trench, or it may take one of the forms shown in Plate IV, Figs. 3, 4 and 5, from the Russian bridgehead at *Liaoyang*.

Care should be taken to protect the roof from an unexploded shell or shrapnel falling at an angle of $\frac{1}{4}$. This may be done by giving it a slope, by interposing a fold of the ground, or by throwing up an earthen mound.

The interior should be separated into small compartments by splinter-proof shields.

Communicating Trenches. Communicating trenches are those constructed to give covered communication between the fire and cover trenches.

"Communicating trenches are frequently necessary in order to connect fire trenches with their corresponding cover trenches, where natural covered communication is impracticable. They are generally rectangular in profile, deep and narrow."—I. D. R.

A trench of the form of Plate IV, Fig. 6, without the seats and with a bottom width of 3 feet will permit the movement of a stretcher through the trench.

"Communication trenches, about three feet deep, and the same measurement across, were made to insure free movement in the defensive line, both laterally and from front to rear. The earth excavated was piled up on the side nearest the enemy."—B. O. R., vol. 2, p. 5.

"The communication trenches were a remarkable feature of the defensive line, and no trouble seems to have been too much to take to make them as perfect as possible. Not only was free movement in every direction possible in the defensive line, but reliefs could be brought up in safety from villages more than a mile in rear."—B. O. R., vol. 2, p. 9. (Description of line of Second Japanese Army on the Sha River.)

"Cover from observation while passing through the trench may insure against loss as effectively as material cover from the enemy's fire." —I. D. R.

Brush planted along a shallow trench on the side towards the enemy will often give the desired concealment.

CHAPTER III

PREPARATION OF THE FOREGROUND, SCREENS, DUMMY WORKS, OBSERVING STATIONS AND OBSTACLES

"The first requirement of a good position is a clear field of fire and view to the front and exposed flanks to a distance of 600 to 800 yards."
—I. D. R.

To secure the best results from the accuracy and rapidity of fire of the magazine rifle, the ground in front of the line of defense should be free from all obstacles which would screen or shelter the assailant.

The distances to objects in the fire-zone should be known, and the advance of the assailant checked while he is under the close fire of the defender. The operations by which these conditions are secured are known as the preparation of the foreground and the construction of obstacles.

Preparation of the Foreground. Standing crops are mowed down and used in covering the parapets of the shelter trenches or are trodden down by the cavalry or infantry.

Piles of stone, wood, straw, and refuse, unless utilized as range targets, are scattered. Brush, orchards, groves, vineyards, etc., are cut down and used in the construction of obstacles, or in filling up dead spaces in the foreground. (A *dead space* is any space as an excavation which cannot be reached by fire from the parapet in its rear.)

Inclosure walls, hedges, embankments, so nearly parallel to the line of defense that they cannot be satisfactorily swept by its fire, are thrown down or removed.

Similar obstructions which are perpendicular to the line of defense or are well swept by its fire, as well as all open obstructions, such as iron and wire fences, are retained.

Buildings are burned, removed or put in a state of defense.

The distances to all conspicuous objects in the foreground, isolated trees, stumps and stones, which are useful in determining the range of the assailant, are carefully measured.

"Poles with conspicuously large tin discs nailed to them were placed to mark the distances in front of the trenches."—B. O. R., vol. 2, p. 630.

Isolated trees and buildings along the line of defense which might be used by the assailant's artillery in determining the range are removed.

Screens. Artificial and natural screens are frequently employed in warfare to conceal works and troops from an enemy.

"When practicable the Japanese always employed artificial concealment for their trenches, covering the freshly turned superior slopes with millet straw, bean vines, or kaoliang stalks gathered from the neighboring fields, or even planting a row of kaoliang stalks in front."—KUHN, p. 112.

Artificial hedges constructed at night to conceal some object or movement in their rear is a device frequently resorted to in warfare.

The Japanese, by this means concealed the strength of a column of troops moving into the valley of the Yalu River from the Russians who were intrenched on heights overlooking the valley.

"Communicating ways, naturally or artificially screened from the enemy's view, sometimes provide sufficient cover for the passage of troops."—I. D. R.

Hedges. In open ground, hedges often serve a good purpose in screening a fire trench.

In utilizing a hedge, a shelter trench is constructed close behind it with its parapet against the hedge. Just above the parapet the hedge is thinned out, so as not to interfere with the view and fire of the defenders, Plate II, Fig. 7.

Dummy Field-works.

"Dummy trenches frequently cause the hostile artillery to waste time and ammunition and divert its fire."—I. D. R.

"Dummy trenches frequently draw the enemy's attention and fire and thus protect the true fire trench.

"Any type is suitable which presents to the enemy the appearance of a true trench imperfectly concealed."—I. D. R.

"After having been over the battle-field, and after having discussed the subject very fully with many officers, I have come to the conclusion that the most important lesson to be learnt from this conflict (Yalu) lies in the contrast afforded by:

"1. The entire absence on the Russian side of any of the ruses or artifices which have from time immemorial played such an important part in battles.

"2. The eager adoption by the Japanese of any ingenious device which might hoodwink their enemies, and thus afford their troops a better chance in the impending conflict."—B. O. R., vol. 1, p. 44.

Obstacles. Obstacles are employed in connection with field fortifications to protect the works from surprise, to break up the assailant's formations, and to hold his troops for a time under the accurate fire of the defender.

"Obstacles placed in front of a defensive position are especially valuable to the defense at night. Many forms of obstacles which would give the attacker little concern in the daytime become serious hindrances at night."—I. D. R.

To be most effective, the location of the obstacles should be concealed from the assailant; they should neither give him cover nor conceal his movements, and they should be difficult to destroy by manual labor, by explosives and by artillery.

Obstacles may be placed either in front of, or along the line of defense.

In front of the line, they are most effective if they are *under the close infantry fire* of the defense and *under close observation at night.*

"The obstacles constructed for the protection of the Shoushanpu position [near Liaoyang] were placed between 300 and 600 yards in front of the trenches, whereas in a line of works recently prepared by the Japanese, barbed wire entanglements and abatis are seen at a distance of only 100 or 150 yards from the parapets.

"Rifle and artillery are presumably the most efficient obstacles to an enemy's advance by day, and as it will rarely be possible to have a double line of obstacles, one near and one at a distance, it would seem best to consider such impediments to advance mainly useful in preventing an enemy from rushing a position by night. For this reason they should be kept close to the position where they can be easily guarded." B. O. R., vol. 1, p. 225.

In the Russian and Japanese works constructed towards the close of the war, the entanglements were placed 25 to 50 yards in front of the fire trenches. (B. O. R., vol. 2, p. 630.)

Obstacles along the line are either in the ditches of the fortifications, or in the intervals between the works of an intrenched line.

For *passive defense,* the obstacles in front of the defensive line should be *continuous;* for *active defense,* they are employed only in the *defense of salients and of key-points.*

Obstacles are also used in connection with field fortifications to close gaps in a line of defense, when the line is too long to be properly defended throughout by the number of available troops, and to obstruct the advance of an enemy along its lines of operation. The latter is most easily done where roads pass through defiles in forests or mountains.

The obstacles employed in hasty field intrenchment are usually *slashings, abatis,* and *entanglements.*

Slashings and Abatis. A *slashing* is formed by felling a belt of trees so that the branches will interlace; the trunks are not wholly detached from the stumps.

A slashing in front of a line conceals the movements of the enemy; it should therefore be made impenetrable except to individuals, and its sides should be well flanked. A slashing 40 to 50 yards wide fulfils the first condition.

"The examination of the enemy's works under cover of the skirmishers of the Sixth Corps developed a part of them which Gen. Wright deemed to be vulnerable to a systematic, resolute attack. The *other* portions in his front were covered by a wide slashing and had a flanking artillery fire."—(Battle of Spottsylvania.) *

Slashings are particularly suitable for obstructing roads, for filling ravines or other depressions in the foreground, and for closing gaps in a line of defense.

An *abatis* is formed by placing one or more rows of trees with their trunks perpendicular to the line of defense and with their branches interlaced and extending towards the enemy. The foliage and small twigs are removed, the large branches pointed, and the trunks firmly pegged to the ground. The whole may be strengthened by connecting the trees with wires, so as to prevent the removal of any single tree.

If in front of the defensive line, the abatis should be placed in a ditch or natural depression, so as to conceal it from the enemy.

If the abatis is constructed some distance from the woods where the trees are cut, it is advisable to use only saplings and large branches and to make it several rows deep. Plate V, Fig. 1.

Care must be taken that the abatis does not conceal the foreground nor interfere with the fire of the defense.

Abatis are also used to close gaps made in a fire trench or breastwork.

"The new intrenchments across the base of the salient were of the most formidable character, being concealed on their right by woods and having on that part of their front a heavy slashing, and on their left front, which was in open ground on the Harrison farm, lines of abatis."*

"Abatis was but sparingly employed [in Russo-Japanese War] owing to the scarcity of timber."—KUHN, p. 113.

* The Virginia Campaign of 1864 and 1865.—GEN. A. A. HUMPHREYS.

"The abatis that I saw was about 9 feet long with a single strand of barbed wire run through the smaller branches. The butt ends of the trees were staked down in the bottom of a V-shaped trench about one meter (3 feet 4 inches) long and 1 foot deep."—B. O. R., vol. 2, p. 641.

Entanglements. An entanglement is formed of stakes, stumps or bushes, connected by wires, ropes or vines, arranged to trip or stop an assailant.

Low Wire Entanglements are formed of short stakes which project 12 or 18 inches above the ground and of wires, preferably barbed, which connect the tops of the stakes. The stakes should be 4 to 6 feet apart and the entanglement 30 feet wide.

The low entanglement is most effective when it is concealed by low brush or high grass. Woven wire fencing may be utilized in the construction of low entanglements.

Low wire entanglements were constructed on several occasions in our Civil War. The usual method was to fasten telegraph wire to bushes and stumps in front of the line, although short stakes were also employed.

A *high wire entanglement* is usually made by driving stakes in rows or in quincunx order about 6 feet apart so as to make a belt 18 to 30 feet wide.

The stakes should be driven or planted *firmly* into the ground and should project above it at least 4 feet.

Horizontal and diagonal wires are attached to the stakes so as to form an impenetrable network. One form of high wire entanglemnt is shown in Plate V, Fig. 2. It would be stronger if the barbed wire fence ran through the middle of the entanglement and if some of the diagonal wires were barbed.

One of the difficulties experienced in making high entanglements is that of driving the stakes firmly into the ground; under such circumstances, the following forms of construction may be employed:

" Between the lines in front of Linshengpu [Sha River] a somewhat novel type of obstacle was noted, the Russians employing a line of ' trestles ' and the Japanese a line of ' tripods.'

"The Russian 'trestles' were about 10 feet long and 4 feet high, made like a large sawbuck, the legs being braced to cross-piece by wooden braces spiked to the legs and cross-piece. The 'trestles' were placed in contact, with their longer dimension perpendicular to the front and barbed wire strung back and forth between them.

"The Japanese 'tripod' consisted of three stout stakes 7 to 8 feet long wired at the middle and the ends spread on the ground. Four rows of 'tripods' were placed in contact, both front and laterally, and barbed wire then strung back and forth.

"The line of Russian 'trestle' obstacle was over 400 yards long, while the line of Japanese 'tripod' obstacle was about 50 yards long. The two lines were less than 100 yards apart at their nearest point.

"Both were exceedingly formidable, and it is doubtful whether a man could have crawled through either of them. They both involved an immense amount of labor in their construction and were devised to meet a special situation, where hostile lines 200 yards apart faced each other for four and a half months. Both were constructed under fire and the mystery is how the work was accomplished."—KUHN, p. 114.

A high wire entanglement in a shallow fire-swept ditch is the best obstacle to defeat night attack, as it is not injured by artillery fire and can be penetrated only with great difficulty and danger. It should always be constructed when material is available and the defense is to be an obstinate one.

Its field of application is in hasty intrenchment when several days are available for preparing the defenses, and in deliberate fortification.

"Wire entanglements both low and high, of the regulation form of construction, were frequently employed by the Russians, but being poorly built (stakes weak and insufficiently driven) and smooth wire being generally used, the obstacle was far from being as effective as it can be made. In this as in other matters the deficiency of suitable material was mainly responsible. The wire employed was largely galvanized-iron telegraph wire. The Japanese employed mainly low wire entanglements."—KUHN, p. 113.

In deliberate field fortification various types of obstacles may be employed. These are *ditches, military pits, stockades, palisades, small pickets,* etc.

Ditches. Before artillery and infantry fire became so accurate, field redouts were usually given a command

of 7 or 8 feet, and the material for the parapet was taken from a ditch 6 feet deep and 10 feet wide which entirely surrounded the work. This ditch properly swept by fire was a strong obstacle. Devices shown in Plate V, Figs. 5 and 8, were sometimes employed to make the passage of the ditch more difficult.

A ditch is invisible at a short distance and cannot be injured by the enemy's artillery fire. To prevent the attacking troops from occupying and securing shelter in it, a ditch must be swept by the defender's fire.

Ditches are still employed in field fortification, but not so extensively as heretofore. Wire entanglements have replaced ditches around redouts of low command.

In the Russo-Japanese War the Russian redouts at *Liaoyang* were surrounded by ditches 6 feet deep and 10 to 15 feet wide. In some of the works about *Mukden* the ditches were omitted and entanglements or abatis substituted.

"In their lines north of Mukden near Chinchiatun the Japanese introduced ditches along several portions of their front. These ditches were located 20 or 30 feet in front of the fire trench and were flanked by field caponiers located at the salients and reentrants and connected to the fire trench by a sunken and covered passageway. The ditches were 6 feet deep, 5 feet wide and had side slopes of 2/1 and 3/1."—KUHN, p. 111.

It will be noted that these ditches were purely obstacles; the material excavated was not employed in the construction of the parapet.

Military Pits. A *military pit* is a conical or pyramidal excavation 2 to 6 feet deep, in the bottom of which is planted a short, sharp stake.

The pits are arranged in quincunx order in three or more rows, in contact with each other or separated by slight intervals; in the latter case the space between the pits is planted with short pickets, Plate V, Fig. 6. A low entanglement may be constructed over the pits.

Deep military pits are sometimes called *trous-de-loups*, being formerly used in Europe to trap wolves.

"In the matter of obstacles, the Russians showed a decided predilection for the deep military pit, constructed strictly on text-book lines, each pit with its sharpened stake at the bottom. Nearly the whole front of the Shoushanpu position [Liaoyang] was covered by a triple and quadruple row of these pits, while all of the redouts of the inner line were similarly surrounded. At the lowest calculation the development of deep military pits in front of the Second and Fourth Japanese armies at Liaoyang must have exceeded a line four miles long, of four rows. The labor expended on this form of obstacle was something tremendous and, in view of its comparative inefficiency, can hardly be said to have been well expended. The deep pits were usually covered with low wire entanglements made of smooth wire easily surmountable." —KUHN, p. 113.

"When the foreign attachés first saw these redouts [Liaoyang] most of them were inclined to scoff at military pits as antiquated obstacles, but the result shows that [deep] military pits covered with a wire entanglement are a very deadly and dangerous form of obstacle."—B. O., R., vol. 3, p. 302.

The Russians probably constructed military pits simply because there were no materials on hand for abatis or entanglements and Chinese laborers were available for such work.

Stockades and Palisades. A *stockade* is a defensible barrier made of upright posts in close contact, Plate III, Figs. 4, 5 and 6, constructed where timber is plentiful, to resist an enemy without artillery.

A *palisade* is simply a barrier of upright or inclined posts also constructed where timber is plentiful, Plate V, Figs. 3 and 4.

Short Pickets, etc. Various devices have been employed, particularly in siege warfare, to prevent attacking troops from creeping along the ground at night in front of the defensive works.

Short pickets, driven at intervals of a foot and then pointed; long wire nails driven through boards which are fastened to the ground with the points of the nails upward; barbed wire fastened close to the ground, are some of the devices that may be employed.

Short pickets in connection with shallow pits are shown in Plate V, Fig. 6.

Inundations. If a stream runs parallel to the line of defense or intersects that line coming from its front, the foreground may be inundated by constructing dams which must be under the close fire of the defense.

An inundation is a difficult obstacle to cross, as it prevents the assailant from securing any cover by the construction of shelter trenches. Pits and ditches, dug before the ground is covered by the water, increase the difficulty of crossing.

"In one case where the ground was favorable, a small stream had been dammed up and formed into an inundation."—(Japanese lines north of Mukden, B. O. R., vol. 2, p. 634.)

Barricades. A barricade is a hastily constructed obstacle to bar the passage of a road, street or other defile. Barricades are used principally in the defense of cities and villages, and are made of paving material, vehicles, household furniture, boxes, casks, etc.

A barricade may be commanded by a parapet in rear, or it may be swept through loopholes constructed in the adjacent houses.

A passage through a barricade is temporarily closed by a *cheval-de-frise*, or by a wagon with chained wheels. A cheval-de-frise, as formerly constructed, was a square log 6 to 8 feet long, to which was fastened a number of strong lances of wood or iron. See Plate V, Fig. 7.

A simpler construction would be to omit some of the lances and connect the others with barbed wire, making a movable wire fence. A number of these chained together, end to end, forms a *chevaux-de-frise.*

The following devices employed in the defense of field fortifications, while not obstacles, are intended to serve the same purpose, viz., to check the enemy's advance and throw his troops into confusion while under the close fire of the defenders.

Land Mines. These are small charges of explosive placed in ordinary shells and arranged to explode either

automatically under the weight of a man or by the closing of an electric circuit. They are planted in front of the work in the ditch or in some depression where they will not be exposed to artillery fire.

"Ordinary earth mines also appear to have been used in the ditches and foreground of some of the redouts of the Russians, as evidenced by the lead wires seen in several of the latter."—KUHN, p. 113.

Fougasses. A stone *fougasse* is a mine so arranged that upon its explosion a sector of the foreground is swept by a hail of stones. It is constructed by excavating a funnel-shaped hole of sufficient size to contain the desired charge of stones. Plate V, Figs. 9 and 10.

At the bottom is placed a box or can containing powder, and in its front resting on a thick plank is the charge of broken or cobble stone. The powder is fired by an ordinary safety fuse or by an electric current.

If placed in front of the ditch of a redout the fougasse should be several yards from the ditch and the excavated earth should be piled on the side toward the work, so that no missiles may be thrown to the rear. The fougasse should be concealed from the enemy by a screen of brush or other light material.

An experimental fougasse, constructed at the Engineer School at Willets Point, with 25 pounds of deteriorated mortar powder, threw its charge of broken stones over an area whose extreme depth was 200 yards.

A fougasse checked a Turkish attack on the Russian defenses in Shipka Pass, during the Russo-Turkish war of 1877–78.

"The old-fashioned fougasse was also used by the Russians, notably at the eastern end of the Shoushanpu ridge [Liaoyang, 1904] where a number appear to have been fired with some success."—KUHN, p. 113.

"Fougasses were occasionally used, as for instance at Port Arthur when, in the night attack on Sung-shu Shan Fort on the night of the 26–27th November, 1904, the Russians exploded three with very disastrous results to the Japanese attacking force."—B. O. R., vol. 2, p. 641.

Removal of Obstacles. The opening of a passage through a line of abatis or entanglement is a difficult and dangerous operation and can be effected only after the fire of the defense has been at least partially silenced. The work must usually be done at night or in a fog.

In the battle of Mukden a pioneer detachment of 50 men, 32 equipped with grenades and 18 with wire cutters, preceded a night attacking party to remove entanglements in front of a Russian trench. They succeeded in their attempt, but 28 of the 50 engineers were either killed or wounded. They had no shields.

A passage is made through abatis by dragging out individual trees and branches.

A passage through high entanglements may be made by cutting the wires and pulling up the stakes. The Japanese engineers devised a steel shield to protect the men engaged in this operation at Port Arthur.

Another way is to attach a number of charges of explosive to a long pole which is pushed into the entanglement. The front end of the pole may be supported on small wheels; the charges must be so attached that the pole can be pushed into the entanglement. The charges are exploded simultaneously.

Low entanglements can be crossed if the fire of the defense is nearly silenced.

Deep ditches are crossed with scaling ladders.

Stockades and palisades are shattered by use of explosives.

CHAPTER IV

REVETMENTS, LOOKOUTS, COVER FOR ARTILLERY AND REDOUTS

Revetments. A revetment is any covering placed upon a slope of earth to enable the material to stand at a greater inclination than its natural slope.

Revetting the interior slope makes the fire of an intrenchment more effective; revetting slopes of traverses, trenches, banquettes, steps, etc., economizes interior space and thus makes the field work a smaller target to the enemy's artillery fire.

Every revetment should, if possible, be protected from direct artillery fire, and the revetment of the interior slope near its top should be made of material like sod, which will neither splinter nor throw dangerous fragments when struck by grazing projectiles.

The revetments usually employed in hasty intrenchments are formed of the material found on the site. *Brush, boards, stones, sods, rubble,* and *sandbags* filled with earth are utilized.

"The scarcity of timber and brush greatly limited the material available for revetment work and sandbags were in consequence extensively used for this purpose. Occasionally sod and stone and less occasionally pickets and kaoliang stalks were employed for revetments. Owing to the natural firmness of the soil, slopes could be maintained at a steep angle in cuts without revetments of any kind, and many of the trenches were constructed in that way."—KUHN, p. 111.

Brush. A brush revetment is formed by driving strong stakes into the ground to retain the brush, which is held in place by the earth packed behind it.

The stakes are at least 2 inches in diameter, are spaced from 1½ to 2 feet, and are driven firmly into the ground. In high revetments the tops of the stakes are connected by a horizontal piece which is held in place by wires fastened to logs or stakes buried in the embankment which the revetment supports. Plate VI, Fig. 9.

Boards, poles, canvas, wire netting, and other materials may be used in the place of brush.

Sandbag. A sandbag is a canvas bag usually 33 inches long and 14 inches wide, which when filled for use in revetments, contains about one-half a cubic foot of sand and weighs about 60 pounds.

A revetment is constructed by laying these bags alternately as headers and stretchers, or as headers alone; the top course should be headers. The openings of headers and the seams of the stretchers should be in the parapet.

Sandbags give no splinters, can be readily transported, and may be used for the entire parapet in rocky or marshy soil where no other material is available.

"There was but an inch or two of earth above the solid rock, so that it was impossible to dig trenches, and the scarcity of loose stones made the building of sangars * very difficult. Later in the siege sandbags, improvised from mealie † sacks, were used to strengthen this part of the line."—(Defense of Wepener.) ‡

Sod. The sod is cut in blocks 18 inches long, 12 inches wide, and 4 inches thick. The blocks are laid grass side down either alternately as headers and stretchers or one tier of headers to three or four of stretchers. Thin pegs 6 or 8 inches long are used to unite the tiers, and the revetment is finished by a layer with the grass side up.

A high sod revetment requires much time and labor. It forms the very best revetment and is very durable.

Brick and Stone. If bricks or loose stones are available, retaining walls may be made of these materials.

* Parapets of loose stone.
† Corn.
‡ History of the War in South Africa, vol. 2, p. 316.

In deliberate field fortification and in siege works various other kinds of revetments are used.

Gabion. A wicker gabion is a cylinder of strong basket-work open at both ends. Its usual dimensions are, diameter 2 feet, height $2\frac{1}{2}$ feet. The weight varies from 30 to 50 pounds, depending upon the kind of material used. The method of construction is shown in Plate VI, Figs. 3 and 4. Details of construction are given in engineering manuals.

In making a gabion revetment, the gabions are placed in line, partially filled with earth, slightly canted to give the desired slope, and then completely filled with earth.

A gabion revetment is very durable and needs no anchorage.

The basket-work of the gabion may be replaced by *hoops of metal*, by *canvas*, by *wire netting lined with bagging or straw*, or by other suitable materials.

Gabions may be replaced by strong *casks*, by *sheet iron* or *straw-board cylinders*, or by similar devices.

Fascine. A fascine is a cylindrical bundle of poles, each 1 to 2 inches thick at the butt, firmly bound by wires at intervals of $1\frac{1}{2}$ feet. Its usual dimensions are, length 18 feet, diameter 9 inches. The method of construction is shown in Plate VI, Figs. 5 and 6. Details of construction are given in engineering manuals. Fascines may be sawed into the desired lengths when short ones are wanted.

A fascine revetment is made by placing the fascines one above another and fastening adjacent layers by pins firmly driven into every two consecutive layers. Every third or fourth layer must be firmly anchored in the parapet.

A fascine is a convenient form of revetment for a step.

High fascine and gabion revetments are made by placing a layer of fascines on each tier of gabions.

Hurdle Revetment. A continuous *hurdle revetment* is similar to the brush revetment, the brush being replaced by a web of rods. The rods are about 1 inch in diameter

at the butts, and are cleared of all twigs. The anchoring wires are wrapped not only around the stakes, but also around five or six of the upper rods of the hurdle so as to hold it in place.

Hurdles, Plate VI, Fig. 8 are similar webs which are transportable; they are usually made 6 feet long and 4 feet wide.

Hurdles are used in the construction of revetments, of roofs, of covered shelters, and of floors of bridges.

In the construction of a revetment, the hurdles are placed side by side, fastened together and anchored to the parapet by wires. The hurdle revetment is stronger and more durable than the brush revetment.

Gabions and fascines have been extensively used in the past in siege works, and were extensively used for revetting in our Civil War. With the disappearance of timber and the introduction of other materials, other forms of revetment will probably be used to a great extent in future wars. In the siege of Port Arthur sandbag revetments were almost exclusively used by the Japanese.

Plank. A plank revetment is made by planting short posts in the banquette, capping them with strong timber and anchoring this framework to the parapet.

The planks are placed in a horizontal or vertical position against this frame and support the parapet.

Timber. A very durable timber revetment was constructed in the defenses of Washington. Plate VI, Fig. 7. It consisted of posts from 4 to 6 inches in diameter, cut into lengths of $5\frac{1}{2}$ feet and set in close contact with a slope of 6/1. The foot of each post rested on a 2-inch plank buried 2 feet under the banquette tread. The posts were capped with a 6-inch timber roughly squared. Anchor-ties of wood were dovetailed into the capping and into an anchor-log buried in the parapet.

Lookouts, Observing or *Conning Stations.*

If the firing trench has no headcover, lookouts should be provided, so that the foreground and the movements

of the enemy may be under constant observation without exposing the defenders. Lookouts should be inconspicuous and have overhead cover.

"By the use of observing stations, the maximum rest and security is afforded the troops. Stations are best located in the angles of traverses or at the end of the trench."—I. D. R.

A lookout along the trench may be made as shown in Plate III, Fig. 12 by roofing the trench with skids and poles, covered with earth, supported in front by the parapet, and in rear by upright posts. The under side of this roof should be at least 8 inches above the bottom of the loophole. The lookout may be closed in the rear by a splinterproof shield as shown.

A seat is provided for the observer.

If the lookout is in advance of the trench, it may be concealed by bushes and is connected with the trench by a communicating trench.

"No projections are allowed above the fire crest, excepting only the *lookout stations*, which are located on the most commanding points a few yards in rear of the fire trench. These are made bombproof and kept as low as possible consistent with having the sighting slit overlook the foreground."—KUHN, p. 111.

Lookouts for commanders of the larger units and for artillery commanders are located some distance in rear of the firing trenches. An inconspicuous platform in a high tree is often utilized for this purpose if no hill overlooks the foreground.

Machine-gun Casemates. Each infantry regiment now has a machine-gun platoon or company with two to six guns. Being a particularly effective measure for defense, the machine-gun should be so mounted as to be protected from the weather and be ever ready for use.

"Throughout the campaign in Manchuria, the Japanese have suffered severely in attacking those points of the Russian front which have been armed with machine guns."—B. O. R., Vol. II., p. 83.

"Machine-gun casemates were also introduced along the parapets, their dimensions being 8 feet wide, 10 feet deep by 3½ feet high with splinter-proof cover some 19 inches thick." (Japanese lines north of Mukden.)—KUHN, p. 111.

Because of the value of machine-guns to the defender the overhead cover of a machine-gun casemate should be as strong as possible. If roofed with railroad rails it will resist the penetration of all ordinary field artillery.

Cover for Artillery.

"In preparing [artillery] positions a most extensive use is made of earth cover."—FIELD ARTILLERY REGULATIONS.

"The Japanese invariably dig cover for their guns before bringing them into action. Only twice have I seen guns brought into action without having gunpits or epaulements prepared for them."—B. O. R., vol. 2, p. 580.

"The Russians, too, almost invariably intrench their guns. On only two occasions have I seen batteries in action in the open, and on both they were out of range of the Japanese guns."—B. O. R., vol. 2, p. 580.

A gun-pit is an emplacement in which the gun and gun squad are partially protected from the enemy's infantry and artillery.

An *epaulement* is an embankment similar to a parapet thrown up to protect a piece of artillery.

The *gun-pit*, constructed both by the Japanese and Russians, was of the type shown in Plate III, Figs. 7 and 8. (B. O. R., vol. 2, p. 580.)

The trenches on either side of the gun were for the gun squad and were frequently covered with a light shrapnel-proof roof. The figure shows the headscreen often employed.

The guns employed in the Russo-Japanese War were not provided with shields.

In the more modern types of field-guns, gun shields and limbers protect the cannoneers from front fire. The epaulements need only be constructed to protect them from oblique or enfilading fire. Sandbags are employed to fill the gap between gun and limber and in making the epaulement near the wheels.

The trenches for the gun squad will be farther to the rear than in the gun-pit shown in Plate III, Fig. 8.

The remaining carriages of a battery, with the horses, are protected by natural or artificial screens at some distance to the rear and flanks of the battery.

"The Japanese are especially good at artificial concealment of guns and wagons, etc., screens or fringes of kaoliang, or screens of boards covered with a few stalks of kaoliang or branches, etc., being used very ingeniously; their artistic temperament helps them to make such things blend with their surroundings. The Russians also make good use of growing crops to hide their guns, but do not pay so much attention to artificial concealment as the Japanese."—B. O. R., vol. 2, p. 580.

Cover for artillery is necessary, even if firing from a concealed position, as the battery is liable at any moment to come under the searching fire of the enemy's artillery.

In deliberate field fortification and siege works, heavy guns are usually mounted in carefully constructed batteries with prepared platforms. The guns are so mounted that they fire either over the epaulement or through notches cut in it. The former is called *barbette* or *over-bank* fire, and the latter *embrasure* fire.

The term *embrasure* is applied to the notch in the parapet through which the gun is fired. Plate III, Fig. 9.

The nomenclature of an embrasure is as follows:

The *throat* is the opening in the interior slope, *ABCD*; the *sole* is the bottom of the embrasure, *BCEF*; the *cheeks* are the side slopes, *ABEG* and *CDHF*; the *sill* is the lower line of the throat, *BC*; the *splay* is the angle made by *EB* and *FC*; the *directrix* is the center line, *K*.

The inclination of the sole is determined by the desired vertical field of fire. If the side *EF* is higher than *BC* the embrasure is *countersloping*.

If the plane of fire is perpendicular to the interior crest, the embrasure is *direct;* otherwise it is *oblique*.

The angle of splay is fixed by the desired horizontal field of fire.

The raised mound on which the gun is placed in Plate III, Fig. 9, is called a *gun bank.*

Fieldworks. The term *fieldwork* is often applied to field fortifications of limited extent.

Fieldworks are usually divided into three classes—*open works, half-closed works,* and *closed works.*

An *open work* is designed to resist attack from the front only and relies on adjacent works to prevent the enemy from getting in its rear.

A fire trench constructed on the lines given in Plate VII, Figs. 1 to 5, would be an open work.

Plate VII, Fig. 3, is a *redan,* of which *AB* and *AC* are the *faces, AD* is the *capital, BC* is the *gorge* and *A* is the *salient* or *salient angle.* Fig. 4 is a *blunted redan.*

Plate VII, Fig. 5, is a *lunette,* of which *AB* and *AC* are the *faces, BD* and *CE* are the *flanks, AF* is the *capital, DE* is the *gorge, A* is the *salient* or *salient angle, B* and *C* are the *shoulders* or *shoulder angles.*

A *half-closed work* is designed to resist attack from the front and also to resist a short enveloping assault.

If the redans or lunette, shown in Plate VII, Figs. 3, 4 and 5, had fire trenches along the faces and flanks and an obstacle along the gorge they would be half-closed works.

A *closed work* is designed to resist an enveloping attack. It is therefore a small area inclosed by a continuous fire trench.

Plate VII, Figs. 6 and 7, are closed works from which infantry fire can be delivered in all directions. Defenders along the faces, *AB, AD* and *BD,* fire to the front; those along the flanks, *BC* and *DE,* sweep the fronts of adjacent works, and those along the gorge, *CE,* fire to the rear.

Fig. 6 is a *lunette;* Fig. 7 is a *blunted lunette.*

The traverses *HI* protect the defenders of the gorge from projectiles coming from the front. A traverse thus placed in the *rear* of a line of troops to protect them from *reverse* fire is called a *parados.*

The entrances to the works through the gorge are protected by the traverses *G*.

Closed fieldworks of this type usually designed for defense by one or two companies of infantry with machine guns are called *redouts*.

Redouts. The term *redout* is usually applied to a *small closed field work.* A large closed work is often called a *fort.*

Redouts were employed in the Russo-Japanese War, as in previous wars, as the supporting points of intrenched positions.

Various types of works were constructed modified to suit site and purpose. The main features of those developed by the war were low command and overhead cover.

"All the field forts and redouts observed at Liaoyang, the Shaho and Mukden were located on level ground in a plain and their traces were perfectly regular.

"The polygonal trace [Plate VII, Figs. 6 and 7] with a broad front and shallow depth best meets the requirements for a closed work under modern conditions, affording a strong frontal fire and a minimum target for artillery. While the reduction in depth of closed works imposed by the searching power of artillery reduces the volume of flank fire and diminishes the value of such works in an extensive fortified line in a flat country, forts and redouts have not lost their importance and are still needed to afford points of support to a defensive line. The employment of machine guns moreover enables small works with short flanks to deliver a volume of fire which makes the size of works and their garrisons a matter of minor importance."—KUHN, p. 110.

One of the Russian redouts is shown in Plate VIII. Of this redout Maj. Kuhn says:

"In my judgment it has the best profile and trace of any seen during the war, affording good cover, small artillery target and strong frontal fire for infantry."

Where the ground was irregular, the outlines of the redouts conformed to the topography.

"The upper summit of each prominent spur was occupied by a closed work, provided with ample blinded cover in the interior and with well-covered deep approaches from the rear, leading up to the continuous fire-trenches which followed the uppermost form line of the hills, but generally some fifty yards (rarely as little as twenty yards) below the actual crest line. This I noticed was the usual position selected by the Russians both here and elsewhere, as the men's heads did not show up against the sky line."—B. O. R., vol. 2, p. 636. (Russian position north of Mukden.)

A redout of the form above described is shown in Plate VII, Fig. 8.

The face *AB* is a fire trench *type A* with traverses and overhead cover as shown in Plate II, Figs. 1, 2 and 3; the flanks *AC* and *BD* are fire trenches *type A* with traverses but without overhead cover; the gorge *CD* is a fire trench *type A* with traverses and overhead cover in the parados *MN*; *E* and *F* are cover trenches for supports; communicating trenches connect the face and gorge; *K* and *L* are latrines; *G* is a dressing station; and *H* is the commanding officer's station. The entire work is surrounded by an obstacle.

The following is the description of the redout shown in Plate VII, Fig. 9, of the Japanese lines north of Mukden.

"The redouts themselves were closed works in the form of blunted lunettes with angles of about 120 degrees at the shoulders.

"The front faces were 100 yards long, the flanks 50 yards, and the work was closed by a straight gorge some 150 yards in length. The ditches were about 10 feet wide at the top and from 7 to 8 feet deep, and were flanked by a double caponier at one shoulder and by a single one at the other. The machine guns were placed in these caponiers but could also be utilized for the general defense of the work. High barbed wire entanglements, well concealed from view, were placed about 60 yards in front of the firing parapets.

"In the center was a blinded conning-tower, to be used as a post of observation by the commanding officer."—B. O. R., vol. 2, p. 635.

A noticeable feature of these Japanese redouts is their size. They were much larger than the Russian redout, Plate VIII, above described.

If the redout occupies an isolated position where it is subject to attack by raiding forces only, as the redouts along a line of communications, concealment is not so essential. A redout with some command will then be preferable, as it is more easily drained and more easily provided with overhead cover.

The same may be said of redouts constructed in wars with tribes not provided with modern artillery.

CHAPTER V

BLOCKHOUSES, BUILDINGS, VILLAGES AND WOODS

Blockhouses. A blockhouse is a defensible barrack in which the garrison is protected from the weather and from the enemy's fire, and from which the garrison can sweep with its fire all the ground in its vicinity.

Blockhouses are used as separate works for the defense of mountain passes, for the protection of the communications in the rear of the army, as isolated posts against an enemy not provided with artillery, and as citadels or keeps in field works.

A *citadel* or *keep* is an interior intrenchment within a fortification to which the garrison retires to prolong the defense, when driven from the main parapet.

Blockhouses may be defended wholly by infantry, or by infantry with machine guns. For long occupation the interior height of the blockhouse should be at least $6\frac{1}{2}$ feet, and 18 square feet of floor space should be allowed for each man; in the blockhouses constructed for the defenses of Washington, D. C., 1861–1863, the height was $10\frac{1}{2}$ feet and the floor space per man was 33 square feet.

The roof must be made fire-proof, the interior properly drained, and the garrison provided with an ample water-supply.

A blockhouse to resist infantry fire may be made of an ordinary unplastered frame building, as shown in Plate VI, Fig. 1, by removing boards so as to leave a horizontal opening or loophole, about 3 inches high and $4\frac{1}{2}$ feet above the floor, entirely around the building.

Below this opening the wall is made bullet-proof by excavating a trench around the building and throwing the earth against the walls.

Headcover is secured by fastening to the studding above the loopholes a steel plate, or a trough 8 inches wide and 1½ feet high, which is rendered bullet-proof by a filling of broken stone or gravel.

The roof should be of tin or of some other fire-proof material.

The walls of a blockhouse may also be of logs, placed horizontally or vertically, or of stone, railway rails, etc.

Formerly it was customary to make the blockhouses of two or more stories, to secure a great amount of fire and to remove dead spaces and sectors without fire. At present this is not considered advisable; an additional tier of fire is secured by surrounding the blockhouse with a trench, as shown in Plate VI, Fig. 1, having an underground communication with the house; the dead spaces and sectors without fire close to the house may be removed by making the blockhouse in the form of a Greek cross.

A *sector without fire* is the sector in front of any salient angle of a fortification which lies between the perpendiculars drawn to the two faces. It cannot be defended by front fire from the adjacent faces.

A blockhouse is generally provided with a cupola, from which an extended view over the surrounding country may be obtained.

Blockhouses of heavy timber, arranged for infantry and artillery defense, were extensively used in our Civil War, to protect the railways in a hostile country.

In the war with the insurgents in Cuba, 1896–1898, the Spaniards used small square or hexagonal blockhouses similar to Plate VI, Fig. 1, in defensive relations with each other, for the lines of defense about the cities and for the *trochas* which extended across the island.

" Large numbers of circular blockhouses were erected in South Africa for the protection of the railways during the war of 1899–1902; they gave

entire satisfaction. They were built of sheets of corrugated iron 6 inches apart, fastened to a wooden framework; the space between the sheets was packed with small stones. The loopholes were frames of sheet iron built into the walls. The entrance consisted of a small hole covered by a movable screen of corrugated iron and stones.

"In order to obtain a maximum fire effect in any direction, the blockhouse was surrounded by a fire trench. The blockhouse itself was only allowed to be used for close defense. The fire trench served also as a protection for the sentry.

"The whole structure could be sent to the required site by train and erected by half a dozen men, carpenters and fitters, in a couple of days." *

A strong defensive post may be made by inclosing an area of some extent with a military obstacle and constructing within the area two or more blockhouses. In our early Indian warfare such posts were constructed by inclosing the area by stockades or palisades. At present, a high wire entanglement would be employed.

Caponier. A *caponier* is a small blockhouse placed in a ditch for the purpose of sweeping the ditch with infantry or machine-gun fire. A *double caponier* is placed at the central point of a long ditch or at the angle of two ditches. A *single caponier* is placed at the end of a ditch and has loopholes in one face only. See Plate VII, Fig. 9.

Buildings. *Masonry* buildings not under artillery fire may often serve the purpose of small redouts or blockhouses in repulsing an infantry attack. Such buildings have often been utilized in European warfare, on battle-fields, in village fighting, and as isolated forts.

Since the advent of torpedo shells, isolated buildings exposed to artillery fire have lost much of their value on a battle-field, but they will still be utilized by outposts in advanced positions. When they are so situated that they are exposed only to infantry fire they may be converted into strong blockhouses.

The first step is to secure a good firing line. This is accomplished by removing all windows and replacing them

* Field Defenses. British Service.

by loopholed shields, high enough to give headcover to men standing behind them. Such shields will probably be most easily made by closing the openings with masonry. Boards nailed across the outside and inside of the window frames and filled with gravel or broken stone may also be employed.

If the walls of the building are not too thick, they may be loopholed for defense as previously described.

A good field of fire should then be secured by clearing the foreground to the desired range.

The doors may be treated in one of two ways:

1. A door may be loopholed, and protected below the loopholes by a mound of sandbags or earth.

2. A redan-shaped stockade, called a *tambour*, may be made in front of the door to give fire parallel to the walls. In front of the exit door a space is left between the tambour and the walls of the building.

If the building has a balcony overlooking the main entrance, which is the natural point of attack, the balcony may be converted into a *machicoulis* by piling up sandbags near the railing and cutting holes through the floor.

A *machicoulis* is any bullet-proof shield which projects beyond the face of a wall and allows vertical fire to be delivered near the face of the wall.

The machicoulis will prevent the assailant from using explosives to blow open the main entrance.

To avoid danger of fire, combustible materials are removed from the building, the floors are covered with earth, and casks of water with buckets are placed in the rooms.

If the building is an isolated one to be held at all hazards, and if time and topography permit, the building may be surrounded by an obstacle and a fire trench.

If the building is only an advanced position from which the defenders are expected to retire eventually, the exit of the building is on the unexposed side and is covered by a *tambour* to protect it against surprise.

The retreat of the troops is then secured by other troops in shelter trenches in its rear who sweep the ground on either side of the building and in its rear.

In the defense of blocks of buildings in cities, the retreat of the garrison is provided for by making doorways through the partition walls. To check the pursuit, some of the partitions may be loopholed.

Villages. In European wars, the villages, which usually consist of an aggregation of strong masonry buildings each surrounded by a strong masonry wall, have usually been important supporting or key points of battle-fields.

In organizing a village for defense, if time permits, the first line should be established 50 to 80 yards in advance of the outer walls to avoid the shrapnel aimed at the village.

A second line of defense is established by putting in a state of defense the outer inclosure walls, hedges, etc.

Exit from the village is covered by intrenchments in the rear.

The artillery is placed in rear of the flanks, where it can sweep the approaches and prevent an enveloping attack.

Communications are made by openings in the walls which separate the adjacent fields or gardens.

As the garrison of a village is intended only for passive defense, obstacles are freely used.

Plates IX and X show the villages and farms of the battle-field of *St. Privat-Gravelotte,* prepared for defense by the French army.

The village of *St. Privat* was the supporting point and *St. Marie-aux-Chênes* the detached post of the Sixth Corps; the village of *Amanvillers* and the *Montigny* château the supporting points and the farm of *Champenois* the advance post of the Fourth Corps; the farms of *Folie* and *Leipsic* the supporting points, and the farm of *Chantrenne* the detached or advanced post of the Third Corps; and the farm of *Moscou* and village of *Rozerieulles* the supporting points, and the *St. Hubert Inn* and the *Quarry,* the advanced posts of the Second Corps.

The village of *St. Privat*, Plate IX, near the right flank of the French position at *St. Privat-Gravelotte*, is a small village of about one hundred masonry buildings with masonry inclosure walls; its south front is about one-third of a mile long.

Three brigades of the Prussian Guard Corps attempted to capture this village by an assault over open ground, about 3000 yards deep, without a previous bombardment of the village by artillery.

The assault was checked 500 yards from the village with heavy loss and the village was captured only when attacked in front and flank by the Prussian Guard and the Twelfth Corps, after the fire of 120 guns had been concentrated upon it. The heavy artillery fire of the Germans not only silenced the French batteries, but almost destroyed the village.

Even with artillery it is sometimes difficult to drive a garrison from a village surrounded by masonry inclosure walls which it has had time to prepare for defense.

In the investment of *Paris*, 1870–1871, the little village of *Bourget*, Plate XI, built along a single road and an intersecting stream, lay about two miles from *Forts Est* and *Aubervilliers*, two of the main forts of Paris and about a mile in front of the French outpost line of defense at *Courneuve*.

It was taken by the German Guard Corps September 20, 1870, in the general investment of Paris.

It was recaptured from the Germans by the French on the 28th of October, 1870. While occupied by three and one-half French battalions with five field guns was for several hours exposed to the fire of *thirty* German field and siege guns at a range of about one and one-half miles; by this fire the garrison lost but *three* men.

It was again captured, October 30th, by nine battalions of German infantry assisted by two field and six horse batteries.

It was then put in a state of defense by the Prussian

engineers and was held despite the fact that it was exposed to the fire of the heavy artillery of the defenses of Paris.

On December 21, 1870, the French attempted to retake this place with three brigades; the attempt was unsuccessful, although at first the place was held by only five German companies. These were only gradually reinforced to fifteen. The attack was prepared by the heavy artillery of the detached forts of Paris, field batteries and a few guns behind iron shields on railway carriages.

In their defense of the village of *Bourget* the German engineers constructed three lines of defense as shown in Plate XI.

The fortification work done in this village consisted in preparing the foreground by blowing up the railway station, and other isolated houses in front of the village; in tearing up, as far as possible, the railway leading towards Paris; in destroying some of the houses and walls in the interior of the village which did not conform to the plan of defense; in constructing barricades of strong profile, bomb-proofs, abatis, shelter trenches with traverses, military pits, wire entanglements and covered communications.

In this country neither the isolated buildings nor the villages which were found upon the battle-fields of the Civil War were of a character admitting defense.

In the Spanish-American war, in Cuba, in 1898, the village of *Caney,* an outpost of *Santiago,* was placed in a state of defense by surrounding it with five blockhouses, four of which were of wood and one of stone; these were constructed on the circumference of a circle whose diameter was about one-third of a mile. Between the blockhouses were trenches for infantry.

In the village itself, a masonry church was organized for defense as a keep. The ground about the village within a range of several hundred yards was generally open and commanded by that upon which the village was built.

The Spanish garrison was said to have numbered 520 men without artillery.

This position was attacked at 7 A.M., July 1, 1898, by a U. S. infantry division consisting of nine regiments, strength about 5500 men, aided by four guns. It was only taken at 4.30 P.M., after the division was reinforced by a brigade of two regiments, bringing its strength to about 6600 men. The loss of the assailants in killed and wounded was 441 men.

The garrison retreated before the village was surrounded, and escaped with a loss of 235 men.*

"The numerous villages that dot the plains of Manchuria were the scenes of many severe combats, and by the nature of their construction lent themselves well to the purposes of defense with comparatively little preparation. The outer inclosing mud walls are usually from 6 to 8 feet high and 2 to 3 feet thick at the base, sufficient to keep out a rifle bullet, except possibly at very close range. These walls could be loop-holed or crenelated quite easily and quickly gave one or two tiers of rifle fire with all needful cover against infantry and artillery fire, excepting high explosive shell."—KUHN, p. 112.

"In the village fighting the mud walls which surround every Chinese village, and which are usually about a foot thick, were found to very readily lend themselves to purposes of defense, and were made use of to the fullest extent by both sides. These walls were not bullet-proof in summer, but became so in winter as soon as hard frost had set in. In addition to the outside wall which surrounds every Manchurian village, every house has its own walled garden, and is itself made of either brick or mud, and each and all of these are capable of affording a very considerable amount of protection. Each side, therefore, did its utmost to forestall the enemy in the occupation of such villages, and some of the most severe fighting in the war occurred in connection with the struggle for their possession. Whenever the Japanese succeeded in wresting such villages from the hands of the Russians, the great value they placed upon such strong defensive *points d'appui* was peculiarly noticeable in the way in which they at once proceeded to put them in a state of defense capable of withstanding any possible counter-attacks. Rough holes were cut through the walls for cover kneeling and standing, and sometimes for firing lying down as well.

"The effect of heavy artillery fire on the villages with high explosives and common shell was very great, but shrapnel fire, owing to a large

* Campaign of Santiago de Cuba, Sargent, p. 101.

amount of cover furnished by the mud walls, had very little effect in the village fighting."—B. O. R., vol. 2, p. 640.

"The defenses made by the Japanese were simple in character, and, at the villages, consisted of a breastwork with headcover, constructed with earth taken from a deeply dug trench, while between the villages were strong shelter trenches with low command. In front, at distances varying from twenty to eighty yards, was a line of barbed or telegraph wire entanglement, abatis or *chevaux-de-frise*, wire being interlaced to render the last two obstacles difficult of removal or passage. Houses and walls were loopholed; but the defensive line was kept outside the former, which merely served as a trap for high explosive shells. The guns were placed behind or between the villages in pits with alternative positions, whence frontal or enfilade fire could be employed at will."—B. O. R., vol. 2, p. 19.

Woods. A grove of *moderate extent*, the approaches to which can be swept by artillery fire, makes a very strong supporting point when properly prepared for defense. It conceals the supports and reserves and partially protects them from the assailant's fire.

The line of defense is fixed 50 yards or more in front of the woods to avoid shrapnel aimed at its edge. The trenches may be protected by an abatis constructed of the trees felled in clearing the foreground.

In the rear of this line a second line for the supports is formed at the edge of the woods. Lean-tos of logs furnish overhead cover for supports and local reserves.

Roads leading into the woods are barricaded; in the interior, trees bordering upon the roads are partially cut through, so that they may be readily felled to close the roads in case of necessity.

Roads for communication between the firing line, supports and reserves, are opened and plainly marked by signs.

If the line of defense passes through a wood of *considerable extent*, it is necessary to throw up practically a continuous line of intrenchment.

Because of the ease with which the assailant can conceal the troops which he may concentrate for an assault, and because of the difficulty of quickly reinforcing every

part of the line, it is advisable to have a second intrenched line of defense, behind which the troops can rally if the first line is pierced.

The edges of large clearings in woods are prepared for defense in the same manner as the outer edge of a grove.

Woods near the flank of a line which cannot be occupied in force are injurious to a defensive position.

Defiles. A defile is any portion of the route followed by a body of troops, over which the troops are compelled to move in column and cannot deploy into line of battle to receive a frontal attack.

A bridge over an unfordable river, a ford, a causeway over a marsh, a deep valley, and a mountain pass, are the defiles which are ordinarily encountered in military movements.

Since a large army marches on as broad a front as possible, with its various columns on parallel roads, when a defile is encountered there is delay in the movement due to the concentration of the army and its passage in a single column.

If the army is moving in retreat before a pursuing enemy, this delay may be fatal unless proper precautions have been made for it in advance.

To prevent disaster in case of defeat, the important defiles in rear of an army, such as important bridges and mountain passes, are usually fortified and garrisoned. It is sometimes equally important to hold the defiles beyond the flanks of the army, to check any movements the enemy may make to turn the flanks by passing through these defiles.

Bridgeheads. The line of fortifications, constructed for the protection of the defile at a river crossing, is called a *bridgehead.* If the works are at both ends of the defile, it is a *double* bridgehead; if at only one end, it is a *single* bridgehead.

When the works are intended to cover the passage of a

large army, the bridgehead is fortified by the construction of a line of redouts several miles from the bridges, so as to give a considerable area within which the army may camp while its units are crossing the river. An inner line is also constructed close to the defile to cover the retreat of the rear guard.

The fortifications of *Washington, D. C., Covington* and *Louisville, Ky., Nashville, Tenn.*, and other important fortifications of the Civil War, were bridgeheads.

The great Russian bridgehead at *Liaoyang*, which covered the railroad bridge and the six temporary bridges constructed by the Russians, inclosed an area 5 miles long and 3 miles deep. Two sides of this area were formed by the Taitzu River, and two by the Russian fortifications.

In this line there were *seven* main forts or redouts, each designed for two companies, and *eight* small redouts designed for one company, besides numerous connecting fire trenches and gun-pits.

The main redouts were lunettes, each having a command of 9 to 12 feet and a ditch 6 feet deep and 15 feet wide. Each was surrounded by wire entanglements and military pits.

The smaller redouts were blunted lunettes each having a command of 4½ feet and a ditch 6 feet deep and 10 feet wide.

Work on the bridgehead was begun about the 1st of April, 1904. It was constructed mainly by Chinese labor.

The bridgehead was successfully held by about three and a half Russian divisions from the night of August 31 to that of September 2, against the Second and Fourth Japanese armies, and was evacuated by order, because of the successful turning movement of the First Japanese army.

In retreating, the Russians were able to take up their three ponton bridges and destroy the others which were not made of transportable materials.

In the defense of this bridgehead the Russian casualties

were about 2400 men, one-half of which resulted from an unsuccessful counter attack; in the attack, the Japanese casualties were 6400 men.

When the main object of the bridgehead is to prevent the use of a defile by small raiding parties, a much simpler construction suffices; such a bridgehead consists of a redout or blockhouse at one or both ends of a defile.

Plate XII shows the plan of two bridgeheads on rivers in Tennessee and Alabama during the Civil War.

CHAPTER VI

EMPLOYMENT OF FIELD FORTIFICATION IN COMBAT

INFANTRY IN THE DEFENSE

THE various successive steps in the employment of field fortification in defensive combat are.

1. The selection of the position.
2. The reconnaissance for the plan of defense.
3. The posting of the troops.
4. The strengthening of the position.

1. *Selection of a position.*

"The defensive having been decided upon, the first duty of the commander is to select the best position available. consistent with strategical requirements and the general plan of operations. The defensive position is generally first chosen upon information furnished by maps."—F. S. R.

It will be observed from the above that the primary considerations governing the selection of a position are *military* and not *topographic.*

The maps will show the lines along which the enemy will probably advance, and also the topographic positions where resistance to such advance is possible.

In selecting a position the commander must first know the approximate length of front he can cover with his command.

"The extent of front that can be covered in an intrenched position depends primarily on the terrain and the degree of resistance to be offered. In the temporary use of intrenchments the resistance offered must be sufficient to repulse an enemy in open attack, and the strength

of the fighting line is gauged accordingly. In estimating the front that can be held against an ordinary frontal attack the calculations are based on the amount of infantry available and may be roughly made as follows;

"For a brigade, of 4500 men in fighting line, one-third may be assigned to the local reserves, one regiment of the brigade or one battalion of each of the three regiments. Six battalions or twenty-four companies will then be available for the fighting line and supports. Each battalion or company furnishes its own support (ordinarily about one-fourth of its strength).

"Assuming 100 yards as the average interval between adjacent companies and 150 yards as that between adjacent battalions, the total front covered by the brigade will be about 4500 yards, approximately two and a half miles, or one yard per man.

"On this basis the following figures show the maximum front that may be occupied under favorable conditions by a unit not acting alone or on the flank of a position :

"Battalion intrenched	750 yds.
Regiment intrenched, one-third as regimental reserve	1500 "
Brigade intrenched, one-third as brigade reserve	4500 "
Division intrenched, one-third as division reserve	9000 " "

—F. S. R.

He must next know what features of a position are desirable for defensive combat.

"*A defensive position should possess as many of the following features as possible:*

"1. A good view of the front and flanks, and within the position itself.

"2. A good field of fire to the front and flanks.

"3. Ground suited to the size of the command, with good communications laterally and to the rear, and with an ample supply of good water.

"4. Shelter from the enemy's fire and concealment from view.

"5. Ground in front that will impede the assailants without furnishing any cover.

"6. Flanks easily protected.

"7. Ground favorable for making local counter-attacks and offensive returns, and for assuming the offensive.

"8. A location that will compel the enemy to attack the position or abandon his advance.

"9. A line of retreat running straight to the rear from the center of the position. If a flank position parallel to the enemy's line of advance is assumed, the flank nearest to the enemy should rest on an impassable

obstacle, and the line of retreat should be perpendicular to the front for some distance in rear of the position."—F. S. R.

"Salients in a position, especially if exposed to concentrated artillery fire, are a source of weakness. If occupied they should be strongly fortified and flanked by artillery and infantry fire."—F. S. R.

"Weak flanks must be made strong either with obstacles, and defensive works, or with troops enough to withstand the probable assaults of the enemy."—F. S. R.

A position that has all these requisites will rarely if ever be found. Skilful tactical dispositions and field fortification must be relied on to make up for its defects.

To secure a good view and an extensive field of artillery fire, the position usually selected is a *divide* behind a stream which intersects the enemy's line of advance. The divide also conceals from the attacker, the defender's reserves and the movements he makes in rear of his firing line.

The ideal *divide* has in its front an open and shallow valley whose width is at least equal to the maximum effective range of artillery.

2. *Reconnaissance.* If possible, the position is reconnoitered in advance both with a view to its possible adoption and with a view to its organization after adoption.

"If possible, a reconnaisance should be made by the commander in person, accompanied by officers of the general staff, artillery and engineers."—F. S. R.

Plan of defense.

"The general position having been selected, the commander forms his *plan of defense*, and issues the necessary orders for occupying the position. This order designates the general line of defense, and divides it into *sections* if necessary and prescribes the distribution and duties of the troops."—F. S. R.

"The principal factors considered by the commander before deciding upon his plan of defense are:

"1. The directions in which the enemy may advance, the probable positions of his artillery, and the use he may make of his cavalry.

"2. The best method of occupying the position in order to check or defeat the enemy, and then to assume the offensive.

"3. The lines of retreat to a new position should the enemy be successful.

The manner of occupying a position varies with the ground and the troops available. No fixed rules can be laid down, the only reliable guides being the commander's good judgment based upon a knowledge of fire and the value of cover, and upon his appreciation of the moral ascendency gained by a timely assumption of the offensive."—F. S. R.

3. *Posting the Troops.*

The troops are now conducted to their section by the subordinate commanders and the various arms are distributed as follows:

"The *infantry* is divided into the *fighting line* and *general reserve.* The fighting line occupies the line of defense and consists of

The firing line,
Supports, and
Local reserves.

The firing line, *habitually intrenched,* is placed so that its fire can effectively meet the enemy's advance, and provision is made to keep it as strong as possible, losses being constantly replaced from the supports. At dangerous points, where the nature of the ground permits, two or more firing lines may be used, thus furnishing banks or tiers of fire. On the other hand, some parts of the position may be more easily defended than others, thus requiring fewer troops. Ground in front with much cover is specially watched, even if unfavorable for the enemy's operations. Dead spaces are swept with fire of special detachments."—F. S. R.

"To delay hostile reconnaissance of the main position as long as possible, *advanced posts* are sometimes established in front or beyond the flanks. The retreat from advanced posts must not mask the fire of the main position."—F. S. R.

"The *supports* and *local reserves* are as near the firing line as practicable and *under cover;* intrenchments with splinter-proof cover being provided if necessary."—F. S. R.

"The *artillery* is posted so as to command the enemy's lines of approach and the probable positions of his artillery. So far as practicable, it is kept in concealed positions, or is screened from the enemy's view. It may be necessary for the greater part of the artillery to occupy a position *in readiness* until the plans of the enemy are disclosed."—F. S. R.

"The *engineers* are employed in opening roads, clearing the field of fire, constructing barbed wire entanglements, setting up and operating searchlights, and otherwise strengthening the position. Engineer officers outline the trenches and other works, and, if practicable, supervise their construction."—F. S. R.

"The *signal troops* establish the lines of information indicated by the

commander; lines are generally run connecting the commander with each section into which the defensive position may be divided, with the artillery, general reserves, and cavalry reserve."—F. S. R.

4. *Strengthening the Position.* The general line of defense for each infantry division will usually be indicated to the division commanders of the firing line by the chief of staff or the chief engineer of the division, and he in turn will assign sections to the brigade commanders posted along this line.

"The defensive works of each section do not, as a rule, form a continuous line, but are arranged *in groups* so as to form a series of *supporting points* on the general line. The works of each group are arranged to provide frontal fire, and fire to cover intervals between groups. Intervals between groups do not weaken a position, provided they can be covered by effective fire from adjacent works. If the enemy resorts to a deliberate method of advance, fortifying himself in positions gained, the intervals may be reduced or closed by interpolated works.

"Groups of fortifications consist essentially of:

"1. Trenches for the firing line, (fire trenches);

"2. Trenches for supports and reserves, (cover trenches);

"3. Sheltered communications between the supports and firing line (communicating trenches);

"4. Obstacles."—F. S. R.

The following is a description of the manner in which the Japanese trenches of the fighting line on the Sha River were occupied. At this point, the Russian and Japanese trenches were separated by only a few hundred yards and they were occupied several months.

"Each sector of the parapet was allotted to one company, and notices were put up all along the parapet showing exactly where the company was located. As a general rule they had a half section [half platoon], about 30 men, under arms as inlying picket, the remaining two and a half sections of the company being in shelters in rear of the parapet. Thus one-sixth of the company was always under arms. One sentry per company by day and two by night was the usual arrangement.

"The shelters for the remaining two and a half sections of the company were built on an entirely different plan. They were about ten yards or so in rear of the parapet, were larger and more comfortable than the shelters of the inlying picket.

"A line of shelters belonging to a company was usually divided up into sections of about fifteen men, and labelled with the number of the group. Each group had its own passage directly into its own section of the parapet where its rifles were stacked."—B. O. R., vol. 2, p. 3.

"Lookout stations for sentries were constructed at intervals.

"There was an advanced post of six men, under a non-commissioned officer, forty yards in front of the parapet, with a communicating trench leading up to it."—B. O. R., vol. 2, p. 5.

A regimental group for the two battalions occupying the fire and cover trenches, as given in the I. D. R., is shown in Plate III, Fig. 11. *A*, *A*, *A*, are the fire trenches; *C*, *D*, *C*, are the communicating trenches; *B*, *B*, *B*, are the cover trenches; *F* is a small closed work for the protection of the flank.

The trenches of each regimental group are then fitted to the site by the commanders of regiments, battalions and companies, and the works are constructed by their troops.

Siting. The *siting* of a field fortification is the determination of its exact position on the terrain.

The principles governing the siting of trenches and obstacles are as follows:

"The location, profile, extent, garrison, etc., of field works are matters to be *decided by the infantry commanders.*"—I. D. R.

"When performing their duties in this connection officers should bear in mind that profile and construction are simple matters compared with *location* and *correct tactical use.*"—I. D. R.

"The first requirement of a good position is a *clear field of fire and view* to the front and exposed flanks."—I. D. R.

"The *length of front* should be suitable to the size of the command."—I. D. R.

"The *natural cover* of the position should be fully utilized."—I. D. R.

"Fire trenches are placed so that troops will *not appear on the skyline*, and are concealed as much as possible."—F. S. R.

"Trenches sufficiently *in advance of the topographical crest* to avoid the skyline are the most easily reinforced and such location is desirable, if sufficient field of fire can be had.

"At *the foot of the slope* trenches are easily concealed and afford grazing fire; on the other hand, the field of fire is apt to be limited, and

they are difficult to abandon or reinforce unless covered approaches are provided.

"Trenches *at the military crest* generally afford a good field of fire and can be easily reinforced and abandoned. They are, however, difficult to conceal and the fire is more or less plunging."—F. S. R.*

"The *trace* of a fire trench or a system of fire trenches depends upon the ground and the proposed density of the firing line."—I. D. R.

"The trenches are laid out in company lengths if possible."—I. D. R.

"Adjacent trenches should afford each other *mutual support.*"—I. D. R.

"The *flanks and important gaps* in the line should be protected by fire trenches echeloned in rear."—I. D. R.

"The most effective protection against artillery fire is *concealment*, and every effort is made to secure it. If possible a prepared position should be examined from the front to ascertain if proper measures for securing invisibility have been taken."—F. S. R.

"When the time and troops are available, the preparations include the necessary cover and communicating trenches, headcover, bombproofs, etc."—I. D. R.

"The *supports* are placed close at hand in cover trenches when natural cover is not available."—I. D. R.

"Commanders fortifying a position estimate, according to the situation, the *relative importance* of the various features of the work—field of fire, cover, communications, etc., and conduct the work accordingly."—F. S. R.

Obstacles.

"If a night attack or close approach of the enemy is expected, troops in a prepared position should construct as numerous and effective obstacles as possible."—I. D. R.

"Obstacles placed in front of a defensive position are especially valuable to the defense at night. Many forms of obstacles which would give an attacker little concern in daylight become serious hindrances at night."—I. D. R.

Tracing. The *trace* of a fortification is the horizontal projection of its principal lines either on a drawing or on the ground itself.

* The military crest is that part of a hill from which all or at least the greater part of the downward slope within range can be seen and subjected to direct fire. It generally differs from the actual or topographical crest, which is at the highest points of the water-shed.

Tracing is the operation of marking the lines of the trace on the ground.

"To locate the trace [of a fire trench] lie on the ground at intervals and select the best field of fire consistent with the requirements of the situation."—I. D. R.

The line thus established, which is marked by pegs connected by a line traced on the ground with a pick, is the *sub-crest* or the projection of the crest; from it, the front and rear lines of the trench excavation are established and traced.

As the top width of the trenches shown in the F. S. R. are based on very steep slopes, these widths must be increased for any soil but stiff, dry, clayey soil.

Intrenching Tools. Tools for the construction of field fortifications now form part of the equipment of every arm.

The infantry usually has two classes of tools: those carried by the individual soldier and those carried by pack or wagon transportation.

The intrenching tools of our army are given in *Appendix C.*

Each infantry squad, consisting of seven men and a corporal, has 3 portable shovels and 1 pick-mattock. Each company has portable handaxes for cutting the stakes and measuring rods employed in laying out the work.

The regimental wagon carries 6 hatchets, 6 axes and 20 machetes per company for clearing the site and the foreground.

Wire cutters are also provided for making entanglements from wire fences, etc., found in the vicinity of the work.

The portable tools of different armies vary in details of construction. In Plate XIII, Fig. 1, is the ordinary form of spade used in most armies; in some services one edge is given a saw edge. Fig. 2, Plate XIII, is the pick

of the German army, Fig. 3 is a flexible handsaw; Fig. 4 is one type of wire cutter.*

Construction of a Company Fire Trench. To construct a fire trench type *A* or *B* with or without attached traverses, the *front and rear lines of the excavation* are first traced on the ground.

The men with shovels are deployed at intervals along this line so that with one or both arms outstretched they will just touch hands. This gives each man a task having a frontage of $3\frac{1}{2}$ to $5\frac{1}{2}$ feet.

The total length of the trench should be such as to give each rifle from a *pace* ($2\frac{1}{2}$ feet) to a *yard* to defend.

Each man begins by tracing a line through his position and perpendicular to the parapet. His task lies to the right of this line and he begins excavating from the line and works towards the right, first making a shallow excavation along the front line of his task and another along the rear line of his task.

With these to guide him he begins on the left, and working towards the right, finishes his task.

Each man supplied with a pick is detailed to assist his squad.

Tasks. The work done by an unskilled workman with *full-sized tools* is usually assumed as about:

Hours.....	1st	2d	3d	4th	5th	6th	7th	8th	day's work
Cubic yards	1	$\frac{5}{6}$	$\frac{1}{2}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	4

This is based on the assumption that the soil is easy to excavate and the earth is neither lifted much nor thrown far.

In soil that must be picked, these tasks must be divided by *two*, and if the soil is frozen, by *four* or more.

With the infantry intrenching tools, the hourly tasks above given must be divided or *two to three*, depending on the depth of the excavation.

* Comparative studies of the Field Equipment of the Foot Soldier, etc., General Staff No. 6, 1906.

It will be observed from the table given above, that speed in excavation with large tools is greatly increased if the tasks are so limited that each man is relieved at the end of *two hours*.

With infantry intrenching tools the relief should be at the end of *one hour*.

With the field equipment the men in each squad form two reliefs of shovelers, using the same tools.

No accurate estimate of the time required for intrenchment can be given, since the time depends on the condition of the men, on the character of the ground, on the condition of the weather and on the tactical conditions under which the work is executed.

It may be necessary to begin with hasty cover for men lying down and develop the trench through successive stages to a trench type *A*.

In constructing a regimental group, the reserve battalion may be employed in clearing the foreground while the other two battalions are engaged in the trenches.

Drainage. Care must be taken to drain all trenches that are occupied by troops in defending a position. In the ordinary fire trench the bottom may be given a slight slope to the rear where a shallow gutter is excavated. This will dispose of any water that falls in the trench. If the trench is so located that it receives the drainage of the surrounding terrain, provision must be made to discharge this water from the trench, if it cannot be diverted before reaching it.

Steps or Ramps. The ordinary company trench may be entered by ramps constructed at the ends of the trench. For direct movements to front and rear, convenient footholds may be made in the trench-slopes if the ground is firm.

Deliberate Fortifications. In constructing deliberate fortifications the works are laid out with greater care than in hasty fortification. If not all, at least the most important works, are laid out by the engineers.

In constructing deliberate works, the ordinary methods employed on civil works are employed. The workmen, whether soldiers or civilians, are organized into gangs of 20 to 40 men for the different classes of work and are supervised by military or civil engineers and foremen who are familiar with such work.

For excavation, the workmen are furnished with full-sized tools and the ordinary daily task is eight hours' work.

Profiling. If the earthwork is a redout or similar work of high command, after the subcrest is marked on the ground the next step is to *profile* the work. This consists in erecting frames or *profiles* of the form shown in Plate XIII, Fig. 5, at intervals along the subcrest. With these profiles to guide them, the workmen can easily shape the parapet.

Laying Out Excavations. Excavations in deliberate works, whether ditches or trenches, are usually divided into rectangles 6 feet long, measured parallel to the subcrest, as shown in Plate XIII, Fig. 6. The tools are distributed along the work as shown in Plate XIII, Fig. 7.

If the embankment and excavation are to balance each other, this is done by so planning them that their areas in the profile plane are equal to each other.

INFANTRY IN THE ATTACK.

"Should the attacking line be stopped by the enemy's fire, it *intrenches* and waits for the second line or for a favorable opportunity to continue the advance."—F. S. R.

"The men must be impressed with the fact that having made a considerable advance under fire and having been checked it is suicidal to turn back in daylight.

"If they can advance no farther, they must intrench and hold on until the fall of darkness or a favorable turn in the situation develops.

"Intrenching is resorted to only when necessary. Troops who have intrenched themselves under fire are moved forward again with difficulty."—I. D. R.

"Supports and reserves occupying intrenchments vacated by the firing line should improve them, but they must not be held back or diverted from their true missions on this account."—F. S. R.

These intrenchments will usually take the form of *asty cover* for men in a prone or a kneeling position.

"In their attacks on the Russian positions, the Japanese firing lines, lines of support and reserves, frequently constructed hasty intrenchments as they advanced over the fire zone. These intrenchments were of the simplest form, to give cover quickly, being thrown up with the portable intrenching tools carried by the soldiers and giving cover lying down or kneeling. They served to cover the successive advances of the infantry line, being occupied in turn by the firing line, lines of support and reserves, and being continuously strengthened by the rearmost lines."—KUHN, pp. 111-112.

"Much spade work has been done by the Japanese infantry during the attack, and no sooner is a point seized than it is secured by intrenchment, no matter how slight. As digging in a prone position is difficult, men are taught in peace time to perform that operation with the light intrenching tool, while exposing themselves as little as possible. In many of the battles of the Second Army the advance, though rapid from point to point, has from start to finish been slow and methodical and the troops have worked their way forward by day and night somewhat as would be done in attacking a fortress."—B. O. R., vol. 2, p. 517.

In the Russo-Japanese War, the Japanese troops who were conducting an offensive campaign, pursued the same tactics as the Union troops in Virginia in the last year of the Civil War. Wherever they encountered the Russians they found them intrenched, and the problem was to force them out of their intrenchments by assault or by turning operations.

The fire-swept zone has greatly increased in width since our Civil War, and the Japanese were longer in reaching a position from which an assault could be made.

Whenever a Japanese infantry unit was brought to a standstill, the men at once threw up hasty cover for a new base of operations. If the position in its front was too strong to be taken by assault, the infantry intrenched itself strongly to resist counter-attack and awaited developments along some other part of the line.

In attacking over frozen ground where the intrenching tool was useless, the Japanese soldier carried *two empty sandbags*, which he filled by scraping the surface of the ground.

"The Japanese made use of intrenchments in attacking the Russians and in defending themselves against counter-attack as freely in the battle of Sha Ho as in that of Liaoyang. Perhaps the fact that the soil of Manchuria is very easily turned is in a measure responsible for the many lines of trenches which mark everywhere the exact positions where the Japanese infantry have been, a remark which might also be applied to the Russians, but these same trenches show a fixed determination on the part of their makers to hold fast to that which they have won, and if it can be avoided, not to give back one foot of ground. In some European armies there might be scruples in ordering troops which had fought all day to dig at night, but none such exist in the Japanese army, and for infantry to pass the hours of darkness in preparing for the engagement of the morrow is a matter of common occurrence."—B. O. R., vol. 1, p. 452.

CHAPTER VII

FIELD FORTIFICATION IN WARFARE SINCE THE INTRODUCTION OF RIFLED ARMS

AMERICAN CIVIL WAR

FIELD fortifications of the hasty and deliberate types first assumed an important role in warfare in the American Civil War, which was the second great war fought with rifled small arms and the first in which rifled artillery took an important part.

Fortified Places. As the Northern and Southern States were separated by a boundary line devoid of permanent land defenses, the first step was to secure for each section a military frontier by the construction of semi-permanent or provisional works.

The Confederate frontier line east of the Mississippi River ran through the fortified positions of *Yorktown, Centerville* and *Winchester, Va., Cumberland Gap, Mill Springs* and *Bowling Green, Ky., Forts Donelson* and *Henry, Tenn.*, to *Columbus, Ky.*

The Union frontier line included the fortified positions of *Washington, D. C.*, and *Covington and Paducah, Ky.*; it was later reinforced by *Louisville, Ky.*, and other less important points.

With the progress of the war, new positions farther to the rear were fortified by the Confederates, and the Union armies strengthened the captured places to form bases for future operations.

Of these later fortified places the most important were *Richmond, Va., Knoxville* and *Chattanooga, Tenn., Corinth*

and Vicksburg, Miss., and *Atlanta, Ga.* Each of the places required one or more campaigns to effect its capture.

The typical Union fortified place was *Washington, D. C.*, the national capital and an important bridgehead on the Potomac River. It was begun in 1861 and completed in 1864. (Plate XIV.)

"Thus from a few isolated works covering bridges or commanding a few especially important points, was developed a connected system of fortification by which every point at intervals of 800 to 1000 yards was occupied by an inclosed field-fort.

"Every important approach or depression of ground unseen from the forts was swept by a battery of field guns.

"Forts and batteries were connected by rifle-trenches which were in fact lines of infantry parapet furnishing emplacement for two ranks of men and affording communication along the line.

"Roads were opened where necessary so that troops and artillery could be moved rapidly from one point of the immense periphery to another or under cover from point to point along the line.

"The woods which prevailed along many parts of the line were cleared for a mile or two in front of the works, the counterscarps of which were surrounded by abatis.

"In the forts all guns were placed in embrasure and well-traversed and well-ventilated magazines ample to contain 100 rounds per gun were constructed.

"Bombproofs were provided in nearly all the forts.

"All commanding points on which an enemy would be likely to concentrate his artillery to overpower that of one or more of the forts were subjected not only to the fires, direct and cross, of many points along the line, but also to that of heavy rifled guns from distant points unattainable by the enemy's field guns." *

At the close of the war, the defenses of Washington (Plate XIV) consisted of 68 forts and batteries and 3 blockhouses which entirely surrounded the cities of *Washington* and *Alexandria*.

The individual forts were bastion forts planned for an average garrison of 500 men and 16 guns.

To conform to the topography of the site, which was

* Defenses of Washington, Maj. Gen. J. G. Barnard, Corps of Engineers, U. S. A.

intersected by the Potomac River, the Eastern Branch, and several small tributaries of these which ran through deep ravines, the works were divided into groups or sections each of which was capable of independent defense.

South of the Potomac there was a second line of works forming an interior bridgehead covering the *Long* and *Aqueduct* bridges.

The garrison of *Washington* was fixed at 25,000 infantry, 9000 artillery and 3000 cavalry, or a total of 37,000 men to defend a line 37 miles long.

This strength was based on two rifles per yard for each front face and one per yard for each rear face of the forts and trenches and three reliefs for each gun.

On account of the supreme importance of the capital a covering army of 25,000 men was deemed essential whenever the enemy should appear within striking distance of it.

Including this covering army the total defending force would be 1879 men per mile.

Nearly all the other important Union places were modeled on *Washington*. Towards the end of the war the bastion trace was, however, abandoned and the outline of the forts became simple polygons without flanking arrangements.

The typical Confederate fortification was that covering both *Richmond* and *Petersburg*.

Richmond itself was surrounded by an inner line consisting of 17 closed works, which were in turn surrounded by two continuous lines of intrenchment.

Petersburg was surrounded by a single line of intrenchment.

The two cities, which are 25 miles apart, were connected by a continuous intrenchment intersected by the James and Appomattox Rivers.

When the Union armies appeared before *Petersburg* in 1864, an intrenched line was extended from the city fortifications westward, a distance of over 10 miles.

The entire line of intrenchment from the north bank of the James River above *Richmond* to its extremity southwest of *Petersburg* was over 60 miles long.*

When this position was finally evacuated in 1865, the Confederates were holding 40 miles of this line with about 57,000 men against a Union force of 125,000.

Fortifications along Lines of Railroad. In the summer of 1862 the Confederate raiders—*Forrest* and *Morgan*—paralyzed military operations in Tennessee by destroying the railroads in hostile country in the rear of the Union armies.

Then began the systematic protection of railroads by intrenched posts.

In his movement from *Chattanooga* to *Atlanta* in 1864, 137 miles, Gen. Sherman was obliged to depend on the railroad for supplies, and he gave the necessary instructions to insure its protection against raiding parties.

"We had strong railroad guards at *Marietta*, *Kenesaw*, *Allatoona*, *Etowah Bridge*, *Resaca*, *Dalton*, *Ringgold* and *Chattanooga*, and at nearly all the regular stations we had small detachments intrenched.

"All the important bridges were protected by good blockhouses admirably constructed and capable of a strong defense against cavalry or infantry."—Memoirs of Gen. WILLIAM T. SHERMAN.

Battlefield Intrenchment. The systematic employment of battlefield intrenchments by the opposing armies was not practiced until 1864, although intrenchments were constructed as early as the *Peninsula Campaign* in 1862.

In organizing the Army of the Potomac for its operations in 1864, a detail of 2 per cent of each infantry division was organized under a captain as a *pioneer detachment* which marched at the head of the division to repair the roads; it was also employed in throwing up intrenchments. Each man carried an axe, pick or shovel in place of his knapsack, which was placed in the detachment wagon.

*W. R. Atlas, Plate 100.

Each army corps had six tool wagons for its intrenching tools.

In the general order opening the campaign, each corps was directed to take with it three of these wagons and leave three in the army train. In the II army corps, the tool wagons followed the leading division of the corps. Each wagon could carry 200 shovels, 50 picks and 30 axes.

Each army corps also had a battalion of engineers composed of three companies. Each battalion of engineers had charge of a ponton train and the reserve tool wagons of the corps.

There were in addition to these battalions, three other engineer battalions in charge of additional bridge trains not assigned to the corps.

All of the engineers were employed in intrenching when such work did not interfere with their duties as pontoniers and road engineers.

Gen. Grant, in describing the operations of the Army of the Potomac in 1864–1865 says:

"In every change of position or halt for the night, whether confronting the enemy or not, the moment arms were stacked the men intrenched themselves. For this purpose they would build up piles of logs or rails if they could be found in their front, and dig a ditch, throwing the earth forward on the timber. Thus the digging they did counted in making a depression to stand in, and increased the elevation in front of them. It was wonderful how quickly they could in this way construct defenses of considerable strength.

"When a halt was made with the view of assaulting the enemy, or in his presence, these would be strengthened or their positions changed under the direction of engineer officers."—Personal Memoirs of U. S. GRANT, vol. 2, p. 205.

To compensate for his numerical inferiority, about 62,000 to 125,000, *Gen. Lee* resorted to defensive tactics in 1864–1865 and also intrenched every position that he occupied from the Rapidan River to Appomattox Court House.

The campaign began about May 1, 1864, with the Army of the Potomac near *Culpeper, Va.* (Plate XXV), and the *Army of Northern Virginia* * at *Orange C. H.* and *Gordonsville*, with outposts along the Rapidan River.

Being warned that the Union army was moving towards *Germanna Ford*, *Gen. Lee* moved towards the same point to attack it before its corps had all crossed the river.

The two armies met in a terrain covered with dense undergrowth called the *Wilderness*, where movements could be directed only by compass. Here was fought the battle of the Wilderness, May 5, and 6, during the course of which both armies intrenched themselves to guard against surprise.

After losing about 18,000 men and finding *Gen. Lee*, too strongly intrenched to warrant further attacks, Gen. Grant left one corps intrenched to cover his communications and with the others made a night march towards *Spottsylvania Court House.*

Gen. Lee, however, also withdrew and succeeded in reaching and intrenching this position before the arrival of the Union army.

The Union army intrenched itself in front of its adversary and from the 8th to the 20th of May, made numerous assaults, but was unable to drive the Confederates from their position.

After losing about 18,000 men, Gen. Grant left part of his army intrenched in front of his adversary and moved eastward to advance along the Richmond and Potomac railroad.

Gen. Lee anticipated this movement and intrenched his army at *Hanover Junction* before the arrival of his adversary.

The Union army intrenched itself in front of these lines, but withdrew without making an assault.

Gen. Grant now crossed the Pamunky River at Hanover

* Names of Confederate commanders amd armies in italics.

Town and found the Confederate army in his front on *Totopotomoy Creek.*

Both armies now shifted southward behind intrenchments and confronted each other near *Cold Harbor.*

Here Gen. Grant on the 3d of June made his last assault north of the James River.

Being repulsed with heavy loss, Gen. Grant again left part of his army intrenched in front of his adversary and withdrawing the remainder marched for Charles City C. H., to cross the James River and attack his adversary's communications at *Petersburg.*

While Gen. Grant was moving southward from the Rapidan, Gen. B. F. Butler landed a force on the south side of the James River at City Point and Bermuda Hundred and made an unsuccessful attack on the defenses of Richmond from the south.

When Gen. Grant was crossing the James River, Gen. Butler was holding the intrenched line of *Bermuda Hundred,* confronted by *Gen. Beauregard* in a similar line.

Gen. Beauregard was able to hold *Petersburg* against the assaults of Gen. Grant until *Gen. Lee* with the main body of the Army of Northern Virginia joined him.

Gen. Grant intrenched his army in front of *Petersburg* and gradually extended his lines to the westward. To prevent *Gen. Lee* from evacuating his lines north of the James River without sacrificing *Richmond* he occasionally made assaults on that front.

By this means, he compelled *Gen. Lee* to extend his front to 35 or 40 miles, too long to be held by his force of less than 60,000 men.

In March, 1865, Grant turned the right flank of *Lee's* long line at *Five Forks* and forced his front at *Petersburg.*

This compelled *Gen. Lee* to evacuate his great intrenched camp and retreat on Lynchburg via Appomattox.

Being in no condition to meet the Army of the Potomac in the open field, *Gen. Lee* was compelled to surrender at *Appomattox C. H.*

By means of intrenchments skilfully utilized, *Gen. Lee* probably prolonged the war nearly an entire year.

By means of intrenchments skilfully utilized, Gen. Grant was able to keep his adversary on the defensive and maneuver him out of position into the open field. Gen. Grant's assaults were costly; his casualties north of the James River were about equal to the strength of the Confederate army with which *Gen. Lee* began the campaign.

The Atlanta campaign of 1864 was conducted on similar lines. Gen. Sherman was obliged to capture and rebuild the line of the Chattanooga and Atlanta railroad as he advanced in order to supply his army.

Knowing this, *Gen. Joseph E. Johnston* successively occupied intrenched lines astride of this road at *Dalton, Resaca, Cassville, Etowah, Kenesaw, Smyrna* and *Chattahoochee.*

Gen. Sherman, who had a numerical superiority of two to one, generally avoided direct assaults and compelled his adversary to evacuate his strong positions by turning movements. The turning columns were usually protected by other troops intrenched and in close contact with his adversary.

He compelled the Confederate army to evacuate *Atlanta* by operating against his adversary's communications with a part of his army, while the remainder was intrenched to cover his own communications.

In describing military operations, Gen. Sherman says:

"When the enemy is intrenched, it becomes absolutely necessary to permit each brigade and division of the troops immediately opposed to throw up a corresponding trench for their protection in case of a sudden sally. We invariably did this in all our recent campaigns, and it had no ill effect, though sometimes our troops were a little slow in leaving their well-covered lines to assail the enemy in position or retreat. Even our skirmishers were in the habit of rolling logs together, to cover their bodies; and, though it revealed their position, I cannot say that it worked to bad effect; so that as a rule, it may be safely left to the men themselves.

"On the 'defensive' there is no doubt of the propriety of fortifying; but in the assailing army the general must watch closely to see that his men do not neglect an opportunity to drop his precautionary defenses, and act promptly on the 'offensive' at every chance."—Memoirs of GEN. W. T. SHERMAN, vol. 2, p. 396.

FRANCO-GERMAN WAR, 1870–1871

As this war was fought in a country dotted with permanent fortifications, it was unnecessary to construct new ones during the progress of the war. Some of the permanent places, notably *Paris*, *Metz* and *Belfort*, were greatly strengthened by field works.

In the great battles of the war, *Worth*, *Gravelotte-St. Privat* and *Sedan* field fortifications were as a rule limited by the French to the modification of the inclosure walls and buildings on the site. These modifications were made by engineers, since the infantry was not equipped with intrenching tools.

The Germans employed the art of intrenchment mainly in the organization of the lines of investment of the great fortified places like *Paris* and *Metz* to repel sorties, but they were also employed in organizing the great battlefield of the *Lisaine* west of *Belfort*, where a German force of 45,000 repelled the attack of a French force of three times its strength. The French army on the *Lisaine* was composed of volunteers of little training.

RUSSO-TURKISH WAR, 1877–1878

The principal incident of the Russo-Turkish war was the defense of *Plevna*, an unfortified village converted into an intrenched camp by field works, which delayed the advance of the Russian army for six months.

In June, 1877, the Turkish forces along the northern frontier consisted of:

1. An army of 90,000 men under the commander-in-chief Abdul Kerim Pasha was in the Turkish Quadrilateral

composed of the fortresses of *Rustchuk, Silistria, Shumla* and *Varna*, guarding the Danube and with outposts on the *Yantra River* (Plate XV).

2. An army of 60,000 men under Osman Pasha was west of the *Vid River*, guarding the Danube from its headquarters at *Widin* to *Nicopolis*.

3. An army of 90,000 men under Suleiman Pasha was in *Bosnia, Herzegovina* and *Albania*.

4. A detachment of several thousand men was in the *Balkan* passes between *Bulgaria* and *Rumelia*.

The Russian army of invasion under *Grand Duke Nicholas* * consisted of the XIV corps, which was to cross the Danube at *Galatz*, near its mouth, and advance towards the eastern front of the Turkish Quadrilateral.

The main body, consisting of *Gen. Gourko's* advance guard and of the VIII, IX, XII and XIII corps, was to cross the Danube at *Sistova*, to be followed later by the reserve, consisting of the IV and XI corps, temporarily held on the north bank.

The seven corps with auxiliary troops numbered about 200,000 men. The field strength of each corps was about 25,000 men.

The XIV corps crossed the Danube about the middle of June and diverted attention from the main force, which began crossing in the last days of June at *Sistova*.

The XII and XIII corps turned eastward to hold in check the army of Abdul Kerim and became the *Army of the Lom*. The XI corps was assigned to this army towards the end of July. During 1877 the *Army of the Lom* remained in position, having numerous small encounters with the Turks.

Gourko's advance guard crossed the Balkan Mountains east of *Shipka Pass*, and, attacking that pass from the south, was in possession of it before July 20. He turned it over to the VIII corps and moved southward.

* Russian commanders and armies are in italics.

Gourko was later driven north of the mountains by Suleiman Pasha, but *Shipka Pass*, being strengthened by field works, remained in the possession of the Russians throughout the war.

On July 10, Suleiman Pasha was ordered to withdraw as many of his troops as could be safely done from Bosnia and Albania and bring them by water to *Constantinople*. He was directed to recapture the Balkan Passes.

The IX Russian corps moved westward from *Sistova* and captured a large Turkish force at *Nikopolis*. It was then ordered to occupy the line of the *Vid River* and guard the right flank of the Russian line.

On the 10th of July Osman Pasha was ordered to move his main force from *Widin* eastward to unite with the other Turkish forces.

He reached the cross-roads of *Plevna* on the 19th of July and on the following day with 14,000 men repulsed a Russian force of 10,000 men who were marching on the same place from *Nikopolis* (Plate XVI).

As it was necessary for the Russians to dislodge Osman before advancing southward, the IX corps was reinforced from the reserve. A division of the IV corps and a brigade of the XI were sent to *Plevna*.

Osman employed the days following his first encounter with the Russians in intrenching his position and in bringing up more troops.

The second attack on *Plevna* was made on July 30, by 32,000 Russians of the IX, IV, and XI corps. Osman repulsed this attack with 20,000 men well protected by field works—redouts and connecting trenches (Plate XVII).

During the month of August the Russians brought reinforcements from Russia and induced the Prince of Roumania to declare war on the Sultan and unite his army of 30,000 men with the troops about *Plevna*.

Osman continued his work of converting *Plevna* into an immense intrenched camp by extending his fortified lines.

The third attack on *Plevna* was made on September 11, after the Turkish works had been subjected to a four days' bombardment (Plate XVIII).

The allied Russian and Roumanian force consisted of about 100,000 men, and the Turkish force of about 35,000 men.

Like the preceding assaults, it was repulsed with heavy loss.

The Russians now abandoned assaults and intrenched themselves in front of the Turkish position. Two additional corps and other troops were sent from Russia to extend the lines and cut off communication between *Plevna* and *Sofia*, Osman's line of supply.

In the latter part of October the *Plevna-Sofia* road was in the possession of the Russians. Shortly thereafter *Plevna* was inclosed by a strong line of Russian field works. On the 10th of December Osman was obliged to surrender (Plate XIX).

At the time of the surrender the Russian force numbered about 120,000 and the Turkish force 45,000.

At no other point did the Russians meet any stubborn resistance. On the 20th of January the Russian advance guard was in *Adrianople* and on the 31st the Turks requested an armistice.

The Russian losses in the three attacks of *Plevna* were—killed and wounded:

1st.	2,845	out of	10,000	of all	arms
2d.	7,305	"	32,000	"	"
3d.	28,731	"	100,000	"	"

The Russian infantry began the war without portable intrenching tools, but each company wagon had a number of shovels, picks and axes. Large numbers of tools were sent to *Plevna* for the use of the troops, and in the march from *Plevna* to *Constantinople* in some of the infantry divisions, these tools were carried by the men on the march.

The value of hasty cover both in defense and attack had been impressed upon them.

In front of *Constantinople* a small intrenching spade similar to that now in use was issued to the troops.

BRITISH-BOER WAR, 1899–1902

The war between Great Britain and the Boer republics of South Africa, the Orange Free State and the Transvaal or South African Republic, was the first war fought with magazine rifles and smokeless powder in which field fortification played an important part.

The Boer army was an army of mounted frontiersmen. The individual Boer was self-reliant, independent and had learned the value of the rifle in hunting and in border warfare. He was an expert in stalking his prey and had no desire to expose his life unnecessarily. He preferred the defensive in warfare, but if he assumed the offensive he sought the advantage of surprise.

The problem of coping with such an enemy was a new one to the British army, whose recent experiences had been with savage or semi-civilized tribes. In the manner of regular soldiers, the British did not at first believe that the untrained Boer militia could offer much resistance.

At the outbreak of the war, Oct. 12, 1899, the British force in South Africa, regular and colonial, was only 27,500 to protect the extensive territories of Natal and the Cape Colony. As the Boers could at once raise a force of 45,000, it was assumed that the British forces would be obliged to remain on the defensive.

Immediately after the outbreak of the war an army corps of about 47,000 men was mobilized in England and sent to South Africa, where the greater part arrived during the month of November.

With this force it was assumed that the offensive could be assumed and the war possibly brought to an end.

Fortified Places. As the British corps from England

would be unable to take the field in South Africa until the latter part of November, the Boers had nearly two months in which to operate unmolested against the towns of *Ladysmith*, *Kimberley* and *Mafeking*, which the Boer authorities decided to capture (Plate XXVI).

None of these towns was fortified before the war, but all were converted into fortified places by means of field works after the outbreak of the war.

At the outbreak of the war, a Boer force of nearly 24,000 was turned in the direction of *Ladysmith*, and driving back the outlying posts, invested that town about the 1st of November, 1900.

The British force invested was 13,500 men, most of them regulars.

In the latter part of November about 6000 men of the Boer investing force were detached to form a covering force.

At the outbreak of the war a Boer force of 7500 men was turned in the direction of *Kimberley*, which was held by 4500 men, only 600 of whom were regulars. The investment began about October 16. About the middle of November, from 2500 to 3000 of the besieging force were detached to form a covering force.

At the outbreak of the war a force of 7000 Boers moved on *Mafeking*, held by 1100 colonial troops. A month after the investment was completed 4000 of the Boers moved southward to *Kimberley*, leaving 3000 to carry on the siege.

The Boers were neither trained nor equipped to carry on regular siege works. The entire siege artillery of both states consisted of four 6-inch guns and four 4.7-inch howitzers.

One serious assault was made on Ladysmith, but as a rule the Boers relied on the moral effect of bombardment and on starvation to reduce these places.

Although the investment of each place was much longer than was deemed probable by the British, each held out until it was relieved.

Ladysmith and Kimberley were relieved in February, 1900, and Mafeking in May of the same year.

Battlefield Entrenchment. On the arrival of Gen. Buller's relieving corps in South Africa it was divided; one infantry division under Gen. Lord Methuen was sent north from *Cape Town* to relieve *Kimberley*, while the other two were sent north from *Durban* to relieve *Ladysmith.*

The *Kimberley* division, about 10,000 strong, found the covering force of Boers, 2500 strong, intrenched along the sky line of a number of kopjes near *Belmont* station. After shelling this position with its artillery, the position was taken by assault with little loss, November 23.

The Boers fell back to *Graspan* station, where another line of kopjes was occupied in the same manner as before. They were driven from this position by assault November 25.

The Boer commander now decided to take up a less conspicuous position and intrenched his men behind the bushes that fringed both banks of the *Riet River* near *Modder* station, where he would be concealed from an attacking force.

In this position he brought the British attacking infantry to a standstill under fire and held them all day, November 28. He retired at night because a small British force had crossed above his position and the entire opposing force might be on his flank in the morning.

The British commander now halted at the river to receive reinforcements and when he again advanced his division numbered 15,000 men and was equipped with 32 field, 1 siege and 16 machine guns.

The Boers had been reinforced to 6000 men with 12 guns and had taken up a position 8 miles long, which was oblique to, but intersected, the railroad along which the British advanced. The left flank of the Boer line rested on the Modder River and the other could not easily be

turned by the British without temporarily abandoning their communications.

Profiting by their experiences, the Boers dug their line of trenches not on the tops of the kopjes and ridges they occupied, but about 250 yards in front of the sky line.

The British commander decided to repeat his former maneuvers and take *Magersfontein Hill* by assault. This hill marked the center of the Boer line and was the most prominent landmark on it. To avoid the losses due to crossing the intervening open ground in daylight the assaulting brigade was to cross it at night.

The assaulting column started a half-hour after midnight December 11, to make its 2½ mile march; shortly thereafter a rainstorm set in which continued through the night. The assaulting brigade reached its destination, in column of masses, about 4 A.M. The battalions were about to deploy when they received a heavy fire from the Boer trenches only a few hundred yards distant.

The column was at once thrown into confusion and all attempts to reach the Boer trenches failed. In the afternoon all hope of an advance was given up and the troops retired in groups behind the artillery which was shelling the Boer trenches over their heads, thus preventing a worse disaster. The other infantry brigades were engaged in protecting the assaulting column from flank attacks.

The Boer position at *Magersfontein* was not again attacked. Two months later, when the British relieving force on the *Kimberley* line numbered about 40,000 men, Field-Marshal Lord Roberts maneuvered the Boers out of this position and surrounded and captured 4000 of them at *Paardeburg*.

The *Ladysmith* relieving force under Gen. Buller found that the Boer covering force had made a stand on the *Tugela River*, astride the railroad, where the Boers occupied a line 9 miles long with a force of 5000 or 6000 men.

With the exception of an isolated hill on the south

bank, the Boer trenches were on the north bank, with the river, 120 to 150 yards wide and generally unfordable, in their front. At the points of attack they were near the river bank and commanded the opposite side. The trenches were inconspicuous and the men were directed to conceal themselves until the British were in close range and to pay no attention to the British artillery during its preliminary bombardment.

The British force of about 20,000 men concentrated on the railroad about 4 miles from the river, and its commander decided to force the crossing at two points, about a mile and a half apart, with his four brigades of infantry after a two days' preliminary bombardment. His mounted troops were to attack the hill on the south side of the river. Nothing could be seen of the Boer intrenchments save a redout constructed by the British themselves at an earlier stage of the war.

The bombardment did not cause the Boers to reveal themselves as the British hoped, and the attack was launched December 15, without any precise knowledge of the strength or position of the Boers.

As a result, the attack became in fact merely a reconnaissance in force, the troops being withdrawn almost as soon as the Boers opened their infantry fire, and it was apparent that the crossing of the river would be difficult if not impossible. In withdrawing, the British commander was compelled to abandon 10 guns of two of his batteries that had come into action within 1200 yards of the Boer infantry.

In January, 1900, the Ladysmith relieving force was increased to 30,000 men and an attempt was made to penetrate the Boer line by crossing the *Tugela River* above the Boer defenses. Gen. Buller succeeded in crossing the Tugela, but in advancing towards Ladysmith he found the Boers occupying a line of kopjes of which *Spion Kop* was the salient.

Being checked on other parts of the line it was decided

to make a night march and capture *Spion Kop*, which it was thought might be a key-point of the Boer position.

It was taken on the night of January 23–24, but could not be properly intrenched both because of the rocky character of the soil and the lack of tools.

Notwithstanding the heavy loss due to convergent infantry and artillery fire it was held until the night of the 24th–25th and then abandoned.

Having failed to secure this mountain top, Gen. Buller withdrew his troops back across the Tugela.

An attempt to cross the kopjes at *Vaal Krantz*, between *Spion Kop* and *Colenso*, early in February being unsuccessful, Gen. Buller returned to the railroad.

He finally fought his way into Ladysmith by capturing in succession the kopjes occupied by the Boers as supporting points, first on the south side of the river and then between the river and *Ladysmith*.

In these attacks, which lasted from February 14 to February 27, each kopje captured served as a base for attacks on the next, and the British commander made good use of his greatly superior artillery.

The total British casualties in the campaigns for the relief of *Ladysmith* were 5500 men, approximately the strength of the Boer covering force.

Lines of Supply.—Field-Marshal Lord Roberts occupied *Bloemfontein*, the capital of the Orange Free State, March 11, and there reorganized his line of supply. He moved northward in May and occupied *Pretoria*, the capital of the Transvaal or South African Republic, June 5.

At the same time Gen. Buller's army advanced northward through Natal along the railroad running to *Pretoria*.

With the capture of *Pretoria*, operations by large Boer forces ceased and the Boers separated into small bodies to attack the British lines of communication, convoys and the small posts established to hold the conquered country.

The warfare by small Boer columns proved very

successful, due to the activity and skill of the Boer leaders, and compelled the British in January, 1901, to resort to the construction of lines of small blockhouses for the defense of the railroads. In June, 1901, lines of blockhouses were constructed across the country to interfere with the free movement of the Boer raiders and facilitate their capture by British flying columns.

At the close of the war in May, 1902, the system included 8000 blockhouses extending over a length of 3700 miles. Between the blockhouses—a half mile apart—ran a strong barbed wire fence.*

RUSSO-JAPANESE WAR, 1904–1905

It is remarkable that after the experience of the Russian army in the Russo-Turkish war, the value of fire action from an intrenched line was not more thoroughly impressed on that army and its troops more thoroughly trained both in the attack and defense of such lines.

The Japanese army, on the contrary, fully appreciated the value of fire action, cover and concealment, and the various difficulties that would be encountered by the attacking troops.

The first important encounter between the opposing armies was at the crossing of the *Yalu River*, May 1, 1904 (Plate XXVII).

The Russian force defending this crossing consisted of the 3d infantry division, 12 battalions, and 3 battalions of the 6th infantry division.

The left wing of the Russian line, which was the only part attacked, was posted on a range of hills which rose from the river (Ai-ho) to a height of 250 to 370 feet. The foreground in front of the greater part of the line was flat and open for several thousand yards and the river itself was waist deep.

This left wing was 8 miles long and was held by seven

* History of the War in South Africa, vol. 4, appendix 2.

battalions with 2 field batteries—5600 infantry and 16 guns.

Although the Russians had occupied this position for over two months, it was very indifferently intrenched with *kneeling* and *shallow standing trenches* without head or overhead cover, and with *shallow gun-pits*. All the intrenchments were very conspicuous; unlike the Boers, the Russians made no attempt to conceal either the men or the works.

The First Japanese Army, assigned to the task of forcing the crossing was composed of 3 infantry divisions, 36,000 infantry, supported by 108 field guns and 20 siege mortars.

The position was carried by direct assault with a loss to the Japanese of 867 killed and wounded.

The lines of retreat from the position being behind one flank, the loss of the Russians was excessive. The casualties numbered about 2200 and the loss in *matériel* included 14 of the field guns and the 8 machine guns.

The Russian commander had a reserve of 5 battalions and 1 battery, but these were too far to the rear to be used on the front line.

Had the position been properly intrenched and the reserve properly posted, the relative losses would have been far different.

The second important battle of the war was that of *Nanshan*. At this position, a ridge from 250 to 350 feet in height extends across the Kwantung Peninsula from sea to sea. Its slopes are intersected by ravines extending into the foreground.

The Russians had two months to prepare this position and did it very thoroughly, constructing 5 *redouts*, 3 *lunettes*, 15 *barbette batteries*, 1 *casemate for four* $3\frac{1}{2}$*-inch guns*, 6 miles of *shelter trench, including communications*, 3 miles of *wire entanglement*, 84 *mines* and *fougasses*, 55 *splinter-proofs* and 9 *bomb-proofs*.

To the defense of this position, two miles long, was

assigned the 5th regiment East Siberian Rifles, 4000 infantry, 57 fortress and 10 machine guns.

The defects of the position were its conspicuous open batteries, shallow standing trenches without headcover, and insufficient traverses in such trenches and communications as were subject to enfilade fire.

Although the Russian corps commander had four other regiments in the vicinity, they were not near enough to reinforce the 5th regiment.

The position was assaulted May 26, 1904, by the Second Japanese Army, consisting of 3 infantry divisions, 36,000 infantry, supported by 198 field guns. It was taken in flank by 12 naval guns mounted on Japanese cruisers.

The Russians were driven from their works after a day's fight in which the Russian casualties were 1400 and the Japanese 4500.

In the attack, the Japanese expended 34,000 shell and shrapnel and 2,200,000 small arms projectiles.

The third important battle of the war was fought near *Liaoyang* August 30 to September 2.

The Russian commander had concentrated at this place 12 infantry divisions of 12 to 16 battalions each. The Japanese commander had in his three armies, First, Second and Fourth, 8 infantry divisions of 12 battalions each and 3 reserve brigades.

Both armies were well supplied with artillery and the Russians had a large Cossack cavalry force.

The operations preceding the battle compelled the Russians, although superior in numerical strength, to remain on the defensive. For this purpose they began preparing the position about the 1st of August.

The Russian position was south of the Taitzu River (Taitzu-ho) and extended in an east and west line about 15 miles.

The east flank rested on the Taitzu River and from that point the line followed a high range of hills running west, for a distance of 8 miles. At this point there was

an intersecting valley nearly 4 miles wide and then a high isolated group of hills, *Shoushanpu*, which formed the right wing. The south front of *Shoushanpu* was 3 miles, and the west front 1 mile, long.

About 2 miles in rear of the right wing, covering the river crossing, was the strong intrenched bridgehead of *Liaoyang*, begun in April.

South of the Taitzu an army corps of 24 battalions occupied the *Shoushanpu Hills*, and two army corps, 56 battalions, occupied the remainder of the line. A division of 12 battalions was in reserve, and a corps of 32 battalions was in the bridgehead.

The remaining 56 battalions of the army were on the north side of the river.

Profiting by previous experience in the war, deep standing trenches with banquettes were constructed on the *Shoushanpu* position, and the foreground being green, the superior slopes were covered with sod.

"This position was remarkable for the deep covered ways which, twisting and turning so as to avoid enfilade, connected the trenches with strong splinterproofs cut in the reverse slopes of the position, and also for the introduction of two semi-permanent works—the one a redout between the western slopes of Shoushanpu Hill and the railway, with a command of 8 feet and a deep V-shaped ditch, and the other a lunette in the valley between the above hill and those to its front. The whole of the front and flanks of the Shoushanpu position, except where roads led through it or a cross-fire could be brought to bear on attackers, was protected by wire entanglements or military pits."—B. O. R., vol. 2, p. 626.

The main Japanese attack was made on the *Shoushanpu* position, which could be attacked from the south and west. Though determined efforts were made by day and night on August 30 and 31 by 54 battalions, the Japanese were unable to take the position.

No serious attack was made on any other part of the Russian line south of the river.

Although the Russian commander had an ample force on the north bank of the river, 56 battalions, to

prevent a turning movement, it was so badly placed that on the night of August 30, a division and a half of Japanese, 18 battalions, crossed the river about 16 miles east of *Liaoyang*.

Having heard exaggerated reports of the size of this force, on the night of August 31, the Russian commander ordered the troops on the south side of the river to abandon the lines they had successfully defended, and cross to the north bank of the *Taitzu*. In the bridgehead, he left $3\frac{1}{2}$ divisions to cover the crossing.

On September 1 and 2 the main Japanese army made unsuccessful assaults on this *bridgehead*, which was well fortified. On the north bank the Russians made vain attempts to dislodge the Japanese turning force, which had been increased to two divisions.

On the night of September 2 the Russian commander withdrew the troops in the bridgehead and the next day began his retreat.

In the battle of *Liaoyang* the Russian casualties were 19,000 and the Japanese 23,000.

In the final battle of *Mukden* the operations were similar to those about *Petersburg, Va.*, in 1864 and 1865.

After the battle of *Liaoyang*, the Russian army retreated to the Hun River (Hun-ho) but later returned to the Sha River (Sha-ho) where one of the corps intrenched itself astride of the railroad.

From this position, in October, the Russians advanced against the Japanese then between the Taitzu and Sha rivers, but were driven back to the Sha River (Battle of Sha-Ho).

Both armies now intrenched themselves very thoroughly by means of redouts, defensive villages, lines of intrenchment and obstacles.

The Russian line began at the village of *Sofantai* west of the Hun River and extended to *Kautulin Pass*, in all about 50 miles. This line was held from west to east by the Second, Third and First Russian armies.

Strong mixed detachments were beyond the flanks of the intrenched line, extending the limits of the defense to 100 miles. Behind this line was the bridgehead of *Mukden* and an intrenched line covering that city from attacks from the west. This line ran northwards from the Hun River parallel to and 3 miles west of the railroad. Its northern extremity was northwest of Mukden.

The Japanese line began at the Hun River west of the village of *Sandepu*, and its eastern terminus rested on the Taitzu River near *Pensihu*. It was held from west to east by the Second, Fourth and First Japanese armies.

From the Hun River to a point 5 miles east of the Mukden-Liaoyang railroad, the two lines were in close contact; east of that they diverged.

In the month of January the Russian commander-in-chief made an unsuccessful attempt to turn the left flank of the Japanese line by an attack on the intrenched village of *Sandepu*.

In the month of February the Japanese commander-in-chief was joined by the four divisions that had captured *Port Arthur* and by a reserve division.

He now planned turning movements about both flanks of the Russian intrenched line.

Two divisions, the Fifth Army, were to advance through the passes 15 to 20 miles east of the Russian intrenched left flank, and the other three divisions, the Third Army, were to cross the Hun River and turn the intrenched village of *Sonfantai*.

The Fifth Army was the first to encounter the Russian outposts. This caused the Russian commander-in-chief to send 5 divisions, from his right wing and reserve, to check this movement.

These reinforcements had just reached their destination when the Third Japanese Army began its movement, March 28, and the Japanese attacked all along the line.

In eight days the Japanese Third Army was northwest

of Mukden, its left flank near the railroad. The Japanese Second Army, which had joined in the turning movement, was north of the Hun River facing the Russian line of intrenchments west of Mukden.

The Russian Second Army had been obliged to conform to this movement and was facing these two hostile armies. Between the railroad and the Hun River the opposing lines had been adjusted to these movements.

East of the Mukden-Liaoyang railroad, the Russian forces were still occupying their intrenched line throughout its extent and the mixed detachments had checked the advance of the Japanese Fifth Army.

As at *Liaoyang*, the Russian commander, fearing the loss of his line of retreat, on the night of March 7, ordered the troops, that had successfully held their lines south of the Hun River, to fall back to the north bank of the river and leave only the bridgehead occupied by Russian troops.

Two days later, when the Japanese forced the line of the Hun, which was frozen and formed no natural line of defense, he ordered the withdrawal of his army to *Tielin*.

In this short campaign the Russians lost 60,000 in killed and wounded and 30,000 prisoners. The Japanese probably between 40,000 and 50,000 in killed and wounded.

The turning movement of the Japanese Third Army might have been more disastrous to the Russians had the latter not had the line of redouts and intrenchments covering *Mukden* on the west. As the campaign took place in freezing weather, it was impossible to do much trench work during the campaign, and had it not been for this line, the Third Japanese Army could have captured Mukden itself.

CHAPTER VIII

PASSAGE OF RIVERS

WHEN an army in the field finds its march interrupted by a river, it may effect the passage of this obstacle by *fords*, by *ferries* or by *military bridges*.

The selection of the place of crossing is determined by a reconnaissance, which should be as detailed and extensive as circumstances will permit.

FORDS

"A river with a moderate current may be forded by infantry when its depth does not exceed three feet, and by cavalry and carriages when its depth is about four feet.

"The requisites for a good ford, are, that the banks are low but not marshy, that the water attains its greatest depth gradually, that the current is moderate and the stream not subject to freshets, and that the bottom is even, hard and tenacious.

"In the mountainous countries the bottom is frequently covered with large stones, rendering the passage of carriages nearly or quite impracticable.

"In level countries the case is often still worse, the bottom, either of mud or quicksand, being impassable for both men and carriages. Sometimes the bottom is composed of fine sand which is hard enough, but which by the action of the hoofs of animals is stirred up and washed away, increasing the depth until the stream becomes unfordable.

"The best bottom is coarse gravel.

"Fords are usually found in the wider and more rapid parts of the river.

"If the position of a ford is not indicated by a road or path leading to the river, it may be determined by sending a number of mounted men across wherever there is a probability of the river being shallow enough.

"The most certain method is to float down the stream in a boat, keeping it in the swiftest part of the current, where the stream is usually

the deepest. Over the stern a sounding-line of the proper length is hung; when this touches bottom the river is sounded across.

"When the ford is discovered, the remarkable objects on the shore should be noted that the place may be easily recognized; and a picket should be planted at the water's edge, in order that any variation in its height may be ascertained.

"Rivers which are not fordable may sometimes be rendered so, when the only obstacle is a too great depth of water over an extent of eight or ten yards, by filling in this portion of their bed with fascines loaded with stones, or with stone and gravel.

"When the water is sluggish or muddy, a ford may be improved by covering the bottom with bundles of coarse grass, rushes or twigs.

"There have been instances of rivers rendered fordable by diverting a portion of the water from its natural course.

"When the stream is wide and rapid, the ford must first be carefully examined and staked out. The troops pass in column, with sufficient intervals to avoid choking the current.

"When boats are to be had, a few should be stationed below the ford to assist men who may be carried down by the current.

"When boats are wanting, this duty may be performed by mounted men, or a life-line may be stretched across supported on casks or other floats. The force of the current may be broken, in a measure, by stationing cavalry in the stream just above the point of crossing." *

"Col. J. C. Barker, Royal Engineers, of the IX division, was told to make provision for the passage of troops across the river near Paardeburg Drift. As the pontoons had been left at Jacobsdal, from lack of transport, the only bridging material was one section of a James' collapsible boat. In this the Royal Engineers carried a rope across the Modder, and then ran some wagons into the ford to break the force of the current. . . . The water was waist-high, and the current was strong. Each section of fours linked arms together and the right-hand men steadied themselves by the rope stretched by the Engineers across the ford." †

"After a freshet the ford should be re-examined, lest some alteration may have taken place in the bed of the river.

"In marching in retreat it is frequently advisable to destroy a ford after having used it. This may be effected by digging trenches across it, or filling in the deepest part with harrows teeth up, plank filled with spikes, crows' feet, etc." *

ICE

"In high latitudes, during the winter, rivers are frequently covered with ice of sufficient thickness to sustain the heaviest loads. This means

* U. S. Bridge Equipage and Ponton Drill.

† History of the War in South Africa, vol. 2, pp. 120 and 126.

of communication should be used with great circumspection. A change of temperature may not only suddenly destroy this natural bridge, but render the river impassable by any method for a considerable time in consequence of the floating ice." *

"With *sound ice*, infantry may pass on 3 inches thickness and cavalry on 4, but with large intervals. Fieldpieces are safe on 6 inches and ice 10 inches thick will carry any load that an army is likely to have.

"Loads may be carried on lesser thicknesses or on unsound ice by distributing the weights. Infantry may cross on lines of planks. The wheels of wagons may be skidded on planks. Wagon boxes may be placed on boards and used as sleds to cross supplies. Animals may be hauled across on platforms."†

FERRIES

In the absence of boats equipped with steam or other power four methods may be employed in propelling boats or rafts across a stream.

1. By means of oars or paddles;
2. By means of poles;
3. By means of a rope or cable stretched taut from shore to shore;
4. By means of a long rope or cable anchored in the stream.

The first method is applicable only to boats or rafts of a moderate size.

The second method is confined to streams of moderate depth and hard bottom.

The third is the method usually employed in ferrying vehicles.

Rope Ferry. If the current is very gentle, the boat may be hauled across the stream by pulling on a rope which passes between guides on the upstream side of the boat or raft. This is called a rope ferry.

Trail Ferry. If the current is swift, a strong cable is suspended above the water by trees or towers and is hauled taut by suitable blocks. One or more pulleys run

* U. S. Bridge Equipage and Ponton Drill.
† U. S. Engineer Field Manual.

along this cable and the boat or raft is held by ropes fastened to these pulleys. This is called a trail ferry.

If the current is less than 3 feet a second, the boat is attached to two pulleys which hold it parallel to the cable. It is then moved by a pulling rope as in the rope ferry.

If the current is more than 3 feet a second, the force of the current itself may be utilized to propel the boat or raft.

The boat is attached to a single pulley and is kept oblique to the current by means of a large rudder or by means of maneuvering ropes as shown in Plate XXII, Fig. 3.

"The most suitable float for the purpose is one composed of two long, narrow and deep boats, with nearly vertical sides. The interval between the boats is such that the current shall act on the sides of both through their entire length, when they form the proper angle (55 degrees) with it."—U. S. Bridge Equipage, etc.

Flying Ferry. In a swift stream, a large boat or raft may be attached to a long rope anchored some distance up stream and propelled across the stream by means of the current, as above described.

If the current is stronger near one shore than the other, the anchor should be placed nearer the latter.

The length of the anchor-rope should be from $1\frac{1}{2}$ to 2 times the width of the stream and it should be supported at intervals by small boats, barrels, logs, etc.

The first float should be as near the anchor as possible without danger of moving it; the others should be arranged to support the cable above the water surface. If no floats are used, the cable should be supported above the water surface by means of a frame on the boat or raft.

The boat is held oblique to the current by maneuvering ropes attached to the anchoring-rope at a point a short distance above the boat.

The construction of trail and flying ferries requires

special materials and appliances and technical training. Landing wharves are usually necessary.

Boats. If the boats of the ponton train are available, about 40 dismounted men fully equipped can be carried in the wooden ponton and 20 in the canvas ponton. These loads crowd the boats and should be carried only when a quick transit of troops is necessary and the current is sluggish.

Scouting parties frequently employ boats found along the river.

An improvised boat may be made by covering a wagon box or frame with tarpaulins.

When cavalry employs boats, the horses are made to swim. If they shun the water, a rope may be stretched across the stream to which 2 or 3 horses are attached on the down-stream side. These horses are pulled across by a number of men.

The horse equipments are carried in the boats.

Rafts. A row boat is not large enough to carry a piece of artillery or an army wagon without taking it apart. To ferry the artillery and trains it is usual to make rafts.

If ponton boats are available, a raft may be made of two ponton boats, as shown in Plate XXII, Fig. 3.

Improvised rafts may be made of casks or other materials of sufficient buoyancy. (Plate XX, Fig. 4.)

MILITARY BRIDGES

Ferries, other than large steam ferries, are suitable only for the movement and supply of small bodies of troops. When large bodies of troops are to be moved or supplied over an unfordable river, bridges affording continuous communication are essential.

A bridge is composed of two parts, the *supports* and the *floor system.*

Supports. The supports of a military bridge are of two classes, *floating* and *fixed.*

Floor System. The floor system comprises the *floor beams* or *cross girders* which rest on the supports, the *stringers* or *joists* which rest on the floor beams, and the *flooring* which rests on the stringers. In a military bridge the floor beams are often called *transoms*, the stringers are called *balks*, and the floor planks are called *chess*. The floor system between the centers of two consecutive supports is called a *bay*.

Width. The width of a bridge for infantry in column of files should be 3 feet; for infantry in twos, cavalry in files and carriages moved by hand, 6 feet; for infantry in fours, cavalry in twos, artillery and army trains, 9 feet. The head room should be at least 10 feet.

Loads. The greatest load to be sustained by a military bridge is that usually employed in designing an ordinary country highway bridge.

1. Its own weight.

2. For the floor system a live load of *80 pounds* per square foot covering the flooring or *6 tons* on two axles 10 feet apart and 5 feet gage. The latter is heavier than the 4.7-inch siege gun, which weighs 8700 pounds; of this weight 6100 pounds is on the rear axle.

3. For the supports, a live load of *80 pounds* per square foot covering the flooring for spans up to 75 feet, *50 pounds* for spans exceeding 200 feet, and intermediate loads for intermediate spans.

Location. The general location of a military bridge is usually determined by tactical requirements. The exact location is frequently determined by such technical considerations as firm banks of the same height, moderate current and good anchorage for floating supports, moderate depth and firm even bottom for fixed supports, etc.

Approaches. To facilitate rapid movement, the approaches should be firm and of easy grade. Easier exit than entrance tends to prevent crowding on the bridge.

BRIDGES ON FLOATING SUPPORTS

Ponton Trains. The conditions that should be fulfilled by a ponton train are:

"The mobility of the train must be such as to enable it to keep pace with all the movements of the column to which it is attached.

"2. The train should furnish the means of ferrying troops promptly and safely, as in case of disembarkations and the passage of a river by force.

"3. It should furnish the means of constructing a bridge capable of passing an army with all its trains over the largest and most rapid rivers, with safety and without delay."—U. S. Bridge Equipage, etc.

To fulfil the first condition, the weight of the loaded carriages of the ponton train accompanying an infantry division should not exceed that of the field gun, or about 4000 pounds, and a lighter equipment should be provided for cavalry commands.

To fulfil the second condition, the supports should be in the form of boats.

To fulfil the third condition, the construction should be such as to admit strengthening to any desired limit.

U. S. Ponton Trains. The bridge equipage of the United States Army was developed by experience in the Civil War. It consists of *heavy* and *light* divisions.

For service in campaign, a battalion of pontoniers with 6 ponton divisions, 4 heavy and 2 light, accompanies each field army.—F. S. R.

Heavy Ponton Division. Each heavy ponton division has all the material for constructing a bridge 225 feet long, with 12 supports. Of these supports, 8 are pontons, 2 are trestles, and 2 are abutments.

Each heavy ponton division is divided into 2 ponton and 2 abutment sections and has in addition 1 tool wagon and 1 forge.

Each *ponton section* consists of 3 ponton wagons and 1 chess wagon and has the material for 3 spans or bays.

Each *abutment section* has 1 ponton wagon, 1 trestle

wagon and 1 chess wagon, and also carries the material for 3 bays.

The ponton wagon carries 1 *ponton*, and 7 *long balks;* when loaded, it weighs about 5000 pounds.

The chess wagon carries 60 *chess* or 60 feet of *flooring,* and when loaded weighs 4000 pounds.

The trestle wagon carries 1 *trestle complete,* 7 long *balks,* 7 *trestle balks,* and 2 *abutment sills;* when loaded it weighs about 5000 pounds.

The *ponton section* is the unit of the division; the division may be increased by adding ponton sections.

The heavy bridge train does not fully comply with the requisites for mobility, since its wagon loads are heavier than those of the field artillery.

Bridge Materials of Heavy Train. The *ponton* is a large flat-bottomed boat, which weighs 1600 pounds and has a displacement of about 10 tons. It is 31 feet long, 5 feet 8 inches wide, and 2 feet 7 inches high at the middle point. Its normal crew is 5 men (Plate XX, Fig. 1).

The *long balks* are of the best light pine, 27 feet long and 5 inches square. The distance between the cleats or *claws* on each balk is 25 feet 8 inches, or 20 feet plus the width of the boat. When the balks span two boats with the claws resting against the outer gunwale of each, the distance between the boat centers is 20 *feet* and the distance between boats 14 *feet and* 4 *inches.*

When one end rests on a trestle or an abutment sill and the other on the outer gunwale of a boat, the distance between the trestle or abutment and boat centers is about 22 *feet* 6 *inches* (Plate XX, Fig. 2), or about 20 *feet* between trestle or abutment and the side of the boat.

The *trestle balks* are 21 feet 8 inches long and 5 inches square. They are 20 feet between outer claws. This makes the distance between the center lines of trestle and abutment sills 20 feet (Plate XX, Fig. 7).

The old-form *trestle*, shown in Plate XXI, Fig. 5, consists of a cap *A*, two legs *B*, two false legs *C*, two shoes *D*, and two suspending chains *E*. In the new form the legs are more nearly vertical, the chains are omitted, and the cap rests on steel pins that pass through the legs.

The trestle must be used when the depth of the water is less than 2 feet.

The *chess* are pine boards 13 feet long and $1\frac{1}{2}$ inches thick. The width of a chess for 2 feet from either end is $10\frac{1}{2}$ inches; the remainder is 1 foot wide. The slot between the ends of adjacent chess is for lashing the side rails.

Construction. In the construction of a ponton bridge, five lines of balks run from abutment sill to abutment sill. These balks usually overlap on the boats and are lashed to both gunwales. Two extra balks are used in bays whose free span exceeds 14 feet 4 inches.

The arrangement of the end of the bridge, when a trestle is used, is shown in Plate XX, Fig. 1.

When the water surface is subject to a change of level a flexible joint must be made at the first ponton. This may be done by using a saddle as in Plate XX, Fig. 2, or the shore balks may be lashed to the shore gunwale of the first boat only, instead of extending across that boat.

The chess are laid on the balks and are held in place by *side rails* that are placed on the flooring over the outer line of balks and are lashed to these balks. The side rails are of the same dimensions as the long balks. The width of the roadway is 10 feet.

Strength. The displacement of the ponton is about 10 tons and the weight of the boat with one bay of the floor system is 2 tons.

A moving load of 8 tons will bring the gunwales to the water level and a load of about $5\frac{1}{2}$ tons will bring the gunwales within 6 inches of the water surface.

"In the month of February, 1862, a ponton bridge of about 60 boats was thrown across the Potomac at Harpers Ferry. The river was then a perfect torrent, the water being fifteen feet above summer level and filled with drift-wood and ice. The greatest difficulty was experienced in pulling the pontons into position, and it was necessary to make use of ship anchors and chain cables to hold them in place. Notwithstanding these unfavorable circumstances, the bridge was completed in eight hours, and the corps commanded by Gen. Banks, with all its trains and artillery, passed over it without accident or delay."

* * * * * * *

"The bridge trains were next transported to Harpers Ferry, where a bridge was constructed a second time, but under entirely different circumstances from that built during the preceding winter. The water was now not deep enough; and, as it continued to subside shortly after the bridge was laid, many of the pontons grounded on a very uneven and rocky bottom. Some of them were completely out of water, yet the heavy trains continued to move over the bridge without seriously injuring them; and when the water rose, most of them floated as well as ever."

With 5 balks between boats, where the free span is $14\frac{1}{3}$ feet, and 7 balks at the ends, where the span is 20 feet, the balks will carry an infantry column estimated at 500 pounds per running foot, or a loaded army wagon of 3 tons, of which two-thirds is on the rear axle.

These loads should not be exceeded unnecessarily without increasing the number of balks and reinforcing the trestles, as the factors of safety for these loads are about 3. A 5-ton wagon has been supported by the balks.

The chess will carry the loaded army wagon; wheel planks should be laid for heavier loads. A 5-ton wagon has broken through the flooring.

If the floor is covered with straw or earth it will deaden the sound made by animals, prevent their slipping, and will also reduce the wear on the chess.

"The mules and oxen, terrified at the swaying of the structure, and by the ringing of their hoofs upon the wooden "chesses" or planks which formed the roadway, refused to move. Some of the mules even flung themselves into the river in a panic, and were swept away and drowned. Rushes and tussocks of coarse grass were then mixed with sand and strewn upon the roadways of both bridges, and the animals,

still suspicious and troublesome, were slowly induced to cross over."—(Passage of the Tugela River in the Spion Kop Campaign.*)

Light Ponton Division. Each light ponton division has all the materials for constructing a bridge 186 feet long on 12 supports. Of these supports 8 are pontons, 2 are trestles, and 2 are abutments.

The light division has 8 ponton wagons, 2 trestle wagons, 2 chess wagons, 1 tool wagon and 1 forge.

The ponton wagon carries 1 *ponton boat*, 7 *short balks* and 16 *chess*, or one complete bay.

The trestle wagon carries 1 *trestle*, 1 *abutment sill*, 7 *short balks* and 7 *trestle balks*.

The chess wagon carries 50 *chess* and 2 extra *ponton covers*.

All of the wagons of the light train are somewhat lighter than field artillery carriages.

Bridge Materials for Light Division. The *ponton* of the light division is a white pine frame covered with canvas. It is 21 feet long, 5 feet 4 inches wide, and 2 feet 4 inches high. It is formed of 2 side frames and 14 transoms, which are held together by a rope which passes through rings in the ends of the side frames (Plate XXI, Fig. 6).

The *ponton cover* is heavy cotton duck which is fastened by ropes to the inner side of the frames.

The ponton complete weighs about 500 pounds and has a displacement of 7.5 tons.

The *short balks* are 22 feet long and $4\frac{1}{2}$ inches square. The distance between cleats is 20 feet 10 inches, or 15 feet 6 inches plus the width of a ponton. If the balk extends over two pontons the distance between centers of pontons is 15 *feet* 6 *inches* and the distance between the boats is 10 *feet* 2 *inches*.

The distance between the boat and trestle centers is about 18 feet.

* History of the War in South Africa, 1899–1902, vol. 2, p. 356.

The *trestles* and *trestle balks* are of the same dimensions as in the heavy train. The distance between trestle and abutment centers is therefore 20 feet.

As the canvas ponton should not be allowed to ground, a trestle is always used in water whose depth is less than the height of the ponton.

The *chess* are 11 feet long and $1\frac{1}{2}$ inches thick. The width of the chess for 18 inches from either end is $10\frac{1}{2}$ inches and elsewhere 12 inches.

Strength. The displacement of the ponton being $7\frac{1}{2}$ tons and the combined weight of the roadway and one boat being about 1 ton, the available buoyancy for live loads is $6\frac{1}{2}$ tons.

A moving load of $4\frac{1}{2}$ tons on the bay will leave about 6 inches freeboard. The 4.7-inch siege gun carriage weighs $4\frac{1}{3}$ tons.

The strength of the roadway is about the same as that of the reserve train. Its width is 9 feet.

Comments. Bridge trains were not thoroughly organized in the Army of the Potomac—Civil War—until the campaign of 1864–1865. In that campaign the army was equipped with 3 heavy and 2 light trains. Of about 60 bridges that were constructed, about two-thirds were canvas ponton bridges. The last 23 bridges constructed for the army were all canvas ponton bridges.

In Gen. Sherman's campaign of 1864–1865 he employed only canvas pontons. The frames were hinged to make them shorter.

It would seem, therefore, that for active campaigning the heavy train has not sufficient mobility and the wagon loads should be reduced.

This may be done by reducing the weight of the boat, the length of the balks, and the length of the chess.

The British service has a wooden ponton that is the size of our canvas ponton and is made in two sections—a bow and a square stern section. An additional bow or stern section may be fastened to the stern section.

One section forms the support for a *light* bridge, two for a *medium* or standard bridge, and three for a *heavy* bridge.

The bay is 15 feet long, and the chess are 10 feet long.

In the German service, the new ponton is a galvanized steel boat 26 feet long which weighs 1100 pounds. A light bridge is made by extending the intervals, as in our own service, and a heavy bridge is made by inserting another ponton in each bay.

The older type pontons of two sections are also used.

The bay is 15 feet long and the chess are 12 feet long.

The German cavalry has a galvanized steel ponton about the size of our canvas ponton, which is made of two similar pointed sections. Each section weighs 300 pounds.

Collapsible canvas boats are also used in the German and some other foreign services, both for ferrying troops and for constructing ponton bridges.

Anchorages. A ponton bridge must be anchored to resist the force of current and wind.

"The distance of the anchor from the bridge should be at least ten times the depth of the stream; with a less distance the bow of the ponton would sink too deeply in the water.

"The direction of the cable when made fast to the bridge must coincide with that of the current, *i.e.*, a ponton in the bridge must have the same position which it would assume if riding freely at anchor.

"The chief of the anchor boat, before turning the cable over to the cable men, must make sure that the anchor has a firm hold on the bottom; if there is any doubt on this point he must recast the anchor.

"It will be remembered that the cable is not finally made fast to the ponton which casts its anchor, but to the one following it in the bridge; and due allowance must be made for this in selecting the place for casting anchor.

"The number of anchors required will depend somewhat on the strength of the current. It is generally sufficient to cast an anchor up stream for every alternate ponton, and half that number down stream; but where the current is very rapid it may be necessary to anchor every up-stream boat, especially near the middle of the bridge.

"The number of anchors cannot be much diminished, however moderate the current, as the anchorage has a very marked effect in

checking the *horizontal oscillation* to which bridges are subject when troops are marching over them; and for this reason it is frequently advisable to increase the number of down-stream anchors. A down-stream cable is never attached to a ponton that is not anchored up stream." *

Methods of Construction. There are four methods of constructing a ponton bridge; by successive pontons, by parts, by rafts and by conversion.

In the method *by successive pontons*, all the materials for the floor system are stored near the abutments; the pontons are rowed into position and the bays are completed, in succession, from one or both abutments.

In the method *by parts*, the materials for the bridge are stored along one or both shores above the site, and are formed into *parts* consisting of two bays; upon each part are stored the materials of the floor system of another bay. The bridge is constructed by rowing the parts into position successively, and connecting them with the completed portion of the bridge, by means of the material of the extra bay carried on each part.

The method *by rafts* is similar to that by parts; the end boat of the raft is, however, lashed to the end boat of the completed bridge instead of being separated from it by a bay. The side rails are spliced by short pieces of wood at the junction of the rafts.

In the method *by conversion*, the materials for the bridge are stored along the bank above the site of the bridge, and the entire bridge is constructed parallel with, and near to, the shore. It is then floated down to the site, and swung into position, pivoting about one of the abutments.

"The main boat bridge was so contrived that the hither end was fastened in place, and so soon as the farther end, which was anchored along shore and upstream, was released, the current threw it into position across the river."—Passage of the Danube before the Battle of Wagram. †

* U. S. Bridge Equipage and Ponton Drill.
† Dodge's Napoleon, vol. 3, p. 297.

Comparison of the Four Methods. The method of construction by *successive pontons* possesses the advantages over the others of being applicable to all the streams, of requiring a minimum quantity of material, the fewest men, and, if the bridge is of ordinary length, the shortest time for its accomplishment.

The labor of constructing a bridge by this method increases rapidly with the number of bays. When, therefore, the bridge is more than *forty bays* in length, the methods by *successive pontons* and by *parts* are combined.

The bridge is commenced, at both ends if possible, by successive pontons, and is pushed on rapidly toward the middle of the stream. The two portions thus formed are connected by parts, which are constructed in the meantime along the river bank above the bridge.

The method by *rafts* may be employed when the bridge is liable to injury from floating bodies, as the portion threatened can be readily disconnected, dropped out of the bridge, and restored to its place when the danger is passed.

This method may be employed by an army hard pressed in retreat, as the rafts are easily disconnected when it is desired to destroy the bridge.

The construction by *conversion* is a delicate operation and can be executed only by well-trained men.

Bridges with Extended Intervals. In a bridge with extended intervals the balks extend only from the gunwale of one boat to the similar gunwale of the succeeding one; the adjacent balks break joints at the boats.

This construction has the advantage of making the bridge one-fourth longer for the same number of pontons, but does not give the same strength or stiffness as the ordinary method. It may be used by cavalry and infantry.

Ordinary Boat Bridges. With some modifications, the principles of construction are the same as those given for ponton bridges.

Since the boats are not usually of a uniform size, the length of the balks for each bay should be proportioned to the capacity of the boat which sustains them, so that the bridge may not be endangered when the bay is crowded with men.

The boat nearest to each abutment must be strong and large, and large boats should be selected for the strongest part of the current, so that the intervals may be as great as possible. The bridge will then offer less obstruction to the current, and will also be in less danger from floating bodies.

The intermediate boats should increase or diminish in size gradually, so as to avoid a sudden change in the level of the roadway.

The gunwales of all the boats should be made approximately on the same level. This is effected by cutting down the larger boats or by loading them until they are sufficiently deep in the water; this latter expedient increases the strain on the cable and should not be resorted to in a strong current. In the smaller boats, the gunwales are raised, or a braced trestle is placed in the axis of the boat for the support of the roadway.

When anchors of sufficient size can be procured, the anchoring of an ordinary boat bridge does not differ from that of the ponton bridge. When this is not the case, anchors may be improvised of boxes or panniers filled with stone, of harrows loaded with stone, of bundles of picks, or by driving piles in the river-bed above the bridge.

Raft Bridges. A raft employed as a support for a bridge should be at least 35 feet in length and should support a load of 15,000 pounds.

If the logs are less than 35 feet in length, a long log is made of two short ones, spliced butt to butt.

If the stream is swift, the raft and logs are pointed to reduce the resistance.

If constructed of round timbers, the logs are laid with the butts alternately up and down stream, and are fas-

tened together, at the ends and under the roadway, by transoms of 6-inch and 8-inch timbers (Plate XX, Fig. 3).

Roadway bearers for the support of the balks are spiked to the middle transoms.

To neutralize the downward pull of the anchoring cable, the center of the roadway should be slightly down stream from the center of buoyancy of the raft.

In this country there are few varieties of unseasoned timber that possess the requisite buoyancy for rafts.

Rafts of Casks.—These rafts may be constructed by forming a frame of timbers to contain the casks (Plate XX, Fig. 4).

The frame consists of four longitudinal pieces halved into four transoms.

The long pieces must be at least 20 feet long, and their distance apart a little less than the head diameter of the casks; the under edges are beveled to give them a good bearing on the casks.

In default of square timber, spars may be used in the construction of the frame. The string pieces and transoms may be spiked or lashed at their points of junction.

The four exterior casks in the raft should be lashed to the frame, otherwise they may be carried off by the current when the raft lurches.

BRIDGES ON FIXED SUPPORTS

The simplest form of military bridge is the one in which the stream is spanned by beams or balks resting upon the abutments.

Assuming the load upon the bridge to be uniformly distributed, the greatest load in pounds which should ordinarily be placed upon a rectangular beam is given by the formula $W = 110 \frac{bd^2}{s}$; in which b and d are respectively the breadth and the depth of a balk *in inches*, and s is the span *in feet*.

If the balks are circular, the formula becomes $W=67\frac{r^3}{s}$; in which r is the radius in inches, and s is the span in feet. The balks are placed 2 to 2½ feet from center to center.

A load of 50 pounds per square foot of roadway corresponds to the ordinary ponton bridge, but a load of 80 pounds per square foot should be provided for in a permanent bridge.

The bridge floor is usually made of chess held in place by side rails or spikes, but may be made of saplings or poles covered with brush or hurdles, and earth.

If the abutments are liable to be washed out by the action of the stream, they are protected by mattresses of brush, or by hurdles weighted down with stone.

Hand rails may be made of posts and poles, lashed or spiked together.

The only difficulty in the construction of such a bridge is the placing of the balks over waterways and deep ravines; this may be done by using shears, a cart, or rollers as indicated in Plate XXI, Figs. 2, 3 and 4.

Trestle Bridges. If the stream cannot be spanned by the balks, one or more intermediate points of support may be formed of trestles. A *trestle* is a frame made of one or more horizontal *transoms*, and vertical or inclined *legs*, strengthened, if necessary, by *sway-bracing*.

Two-legged Trestles. Plate XXII, Fig. 6, shows the ordinary form of a *spar trestle* with two legs, in which AB and CD are the transoms, AC and BD the *legs*, and AD and BC the *sway-braces*.

If the height of the upper transom above the ground does not exceed 12 feet, the size of square or circular legs may be determined by the formula $W=300\ A$; in which W is the safe load and A is the area of cross-section in inches. The coefficient 300 is decreased by 10 for every foot of increase in height above 12 feet.

The size of the upper transom is computed by the

formula for the strength of a balk, assuming that the transom supports an entire bay.

The flooring is constructed as in the single-span bridge described above. For a bridge 10 feet wide with 15-foot bays, the legs should be about 5 inches square.

In constructing a spar trestle bridge *on land*, the axis of the bridge is marked on the ground, and also the position of each trestle.

If the span is short, the height of the upper transoms or the length of the legs of each trestle may be determined by stretching a cord along the axis of the bridge between the abutments and measuring the height of the cord at each trestle site; if the span is too great for this method, a profile may be made of the depression between the abutments.

If the ground is very irregular, the length of each leg must be determined by cords or profiles along each side of the bridge.

In constructing a bridge over a stream, a similar method may be employed, by driving poles at the site of each trestle along the axis of the bridge, and measuring the height of the desired level of the upper transom above the water level and the bottom of the stream; or a profile of the bottom of the stream may be constructed from careful soundings.

Having the width and height of each trestle, rough drawings of them may be made for the framing party. The different pieces are fastened together with lashings, with spikes or with iron dogs.

Trestles on land are easily erected by the use of pushing-poles and rope-guys, as employed in the erection of telegraph poles.

In the water they are sunk into place by employing a boat to carry them to the proper site, or by the use of two long poles as shown in Plate XXII, Figs. 1 and 2.

In Fig. 1, the outer ends of the poles rest upon the bottom, and the trestle is allowed to slide down them into

place; it is then raised to an upright position by means of pushing poles.

In Fig. 2, the poles are used as cantilevers to support the trestle. The latter is pushed with poles along the cantilevers until it is over the proper site, and is then lowered into place by canting the supporting poles. In maneuvering the trestle, ropes are attached to the bottoms of the legs as indicated.

Framed Trestles. When squared timbers or planks are available, a framed trestle may be constructed.

In a framed trestle, the upper transom is fastened to, and rests on, the tops of the legs, and is called a *cap sill;* the legs are fastened to, and rest on, the lower transom which is called a *ground sill,* or *mud sill.* In erecting the trestle, the ground sill is carefully leveled.

Tripod Trestle. A tripod as usually constructed is an A frame, to the vertex of which is fastened a third leg. The plane of the A frame is parallel to the axis of the bridge and the floor beam or cross girder of the floor system rests on the cross-bar of the A, whose position on the legs may be altered to suit the height of the roadway.

Adjustable tripod trestles are used in some foreign services instead of two-legged trestles.

Pile Trestles. In marshy ground the ordinary trestles settle unevenly; it is better, on such ground, to construct pile trestles.

A *pile trestle* or *bent* is simply a row of piles crowned by a cap sill and strengthened by sway-bracing if necessary (Plate XXII, Fig. 8).

If the piles are small they may be driven with mauls from a temporary platform (Plate XXII, Fig. 7); if large, they are driven with a movable pile-driver, operated by man or steam-power. A pile driver in which the ram is raised by men pulling on ropes is called a *ringing engine.* One can be easily constructed in the field. Other forms of temporary platforms are given in the Engineer Field Manual.

Crib Bridges. The supports of a bridge may be *cribs* formed of rough logs halved into each other near their ends and fastened together with spikes or treenails.

Cribs filled with stone form excellent supports in a stream with a rocky bottom and swift current.

A low support for a viaduct may be formed of two rows of posts, placed a few feet apart and tied together with wire, to retain a pile of fence-rails, planks, or logs (Plate XXII, Figs. 4 and 5).

Lock or Strut Bridges. Where the abutments of a bridge are high and firm, and the span is not too great, *lock* or *strut bridges* may be constructed; these consist of two frames, similar to the spar trestle, which form inclined struts for the support of the bridge.

A *single-lock* bridge has one intermediate support for the roadway between the abutments; a *double-lock* bridge, two; and a *single-sling* bridge, three.

A *single-lock bridge* is made up of two trestle-frames (Plate XXII, Fig. 6), which rest on the abutments, below the roadway, and are so inclined that the frames cross each other below the level of the roadway; the legs of each rest upon the upper transom of the other. A roadway-bearer rests upon the legs at their intersection. This type is suitable for spans of from 25 to 35 feet.

In the *double-lock bridge* (Plate XXI, Fig. 1), the two inclined trestle-frames do not cross each other, but are held apart by a horizontal strut. This strut is firmly fastened to the upper transoms, and supports two roadway-bearers. This type is suitable for spans of 30 to 40 feet.

The *single-sling bridge* is similar to the single-lock, but the frames cross each other several feet above the roadway. The upper transoms, at the level of the roadway, form two roadway-bearers, and a third is suspended from the cross, formed by lashing together the legs of the two frames. This type is suitable for spans of 40 to 50 feet.

Lock and strut bridges are suitable for replacing bridges destroyed by an enemy when strong masonry piers or abutments have been left standing.

Other Bridges. The bridges described in this chapter are those that form part of the regular organization of an army, or can be readily constructed with the tools included in the equipment of all field troops and of the materials found on any site. In engineering manuals will be found descriptions of the more complicated truss and suspension bridges which are constructed by the engineers. In some foreign services a transportable steel truss has been adopted to replace any railway bridge which may be destroyed by an enemy.

CHAPTER IX

MILITARY DEMOLITIONS

A MILITARY demolition is the destruction by an army of any object in the theater of war, whose preservation would be injurious to the army itself, or useful to the enemy.

Demolitions are of service in both defensive and offensive operations.

In defensive operations they serve to clear the foreground, and to improve communications upon the battlefield; to destroy communications, fortifications, and munitions of war on a retreat; and to destroy, by means of raids, the lines of supply in rear of a pursuing enemy.

In offensive operations, they serve to destroy lines of communication or operation which may be useful to the enemy, or to destroy the resources of any portion of the enemy's base.

In our Civil War, both sides made extensive use of military demolitions to frustrate military movements.

The most notable examples were:

1. The destruction of the *Louisville-Nashville*, and *Nashville-Chattanooga* railroads, in rear of the Army of the Cumberland, by the Confederate cavalry commanders *Forrest* and *Morgan* in 1862-63, thus interfering with the supply of the Union Army, and preventing any forward movement.

2. The destruction of the resources of the *Shenandoah Valley, Virginia*, by Gen. Sheridan in 1864, to prevent its future use as a line of operation by which the Confederate Army might invade the Northern States.

3. The destruction of the railroads in his rear, by Gen. Sherman in his "March to the Sea," thus preventing pursuit, and also cutting the communications between the Seaboard and Gulf States.

4. The complete destruction of the resources of that portion of the Confederate base of operations formed by the Gulf States east of the Mississippi, by Gen. James H. Wilson in 1865.

In offensive operations, demolitions are usually executed by the cavalry, and in the European armies squads of cavalry are temporarily attached to companies of engineers for training in these duties.

In our service, this duty would be performed by the engineer companies attached to a cavalry division.

In defensive operations, the most important demolitions are executed by the engineer companies attached to the infantry divisions or corps.

Means of Destruction. Intrenching tools, fire, and explosives are the principal means of effecting demolitions.

The particular means employed depends upon the size of the working party, the character of the object to be destroyed, and the period of time within which the work must be executed.

Explosives. The requisites of an explosive for military purposes are *safety*, *stability*, and *simplicity* in use. Experience has shown that *gunpowder*, *dynamite*, *racka-rock*, *guncotton* and the *picric-acid compounds* are the most suitable explosives for demolitions.

The explosive compounds have the advantage over gunpowder of being more powerful and of requiring less careful tamping; in fact they may be employed without any tamping whatever, but the explosive effect is very much reduced.

Gunpowder. If gunpowder is used the following points should be noted:

1. The fine and quick-acting grades are the most powerful.

2. The charge should be well tamped.

3. Numerous points of ignition are advisable in large charges.

4. Large denotators or electric fuses are superior to other modes of ignition.

5. The powder must always be kept dry.

6. Charges of gunpowder are placed in water-tight bags or casks.

Dynamite. Dynamite, under ordinary conditions, may be handled with safety, but is liable to give severe headache and nausea to persons unaccustomed to handling it.

If the cartridges are kept in a damp place, or are exposed to the direct rays of the sun or to high heat, the nitro-glycerine exudes and the dynamite becomes exceedingly sensitive.

If exposed to a temperature of about 40° F., dynamite freezes, and although detonated with great difficulty, it should never be used in this condition.

It may be thawed by placing it in a warm room, keeping it protected from the direct rays of the fire, or by placing the sticks in a double boiler similar to a glue-pot; the outer boiler contains warm water and the inner one the dry sticks of dynamite.

Dynamite is more sensitive to percussion than the other explosives mentioned. It does not explode if exposed to a blow of wood upon wood; it may explode if exposed to a blow of stone upon stone, and will usually explode if exposed to a blow of metal upon metal, unless the metals be copper or lead.

It is extensively manufactured in this country in several grades under the names of Atlas Powder, Giant Powder, Hercules Powder, etc., and is employed in blasting, mining, etc.

The most powerful contains 75 per cent of nitro-glycerine and is called dynamite No. 1.

Dynamite that contains 60 per cent is recommended

and is usually found in the market in cylindrical cartridges 8 inches long, with diameters of $\frac{7}{8}$, $1\frac{1}{4}$, and 2 inches.

The cylinders are wrapped in paraffined paper, and are packed in sawdust in wooden boxes containing 50 pounds each.

Dynamite should be stored in a dry, well-ventilated place.

Racka-rock. This is an explosive formed by saturating a linen cartridge of potassium chlorate in nitro-benzol.

The two substances are each non-explosive and may be transported separately without danger—the chlorate cartridges in boxes and the liquid benzene in cans. The cartridge is soaked in the liquid just before using.

Racka-rock is found in the market in cylindrical cartridges similar to those of dynamite, and is preferred to other explosives by many military engineers, on account of its safety in transportation and storage. It is somewhat more expensive than dynamite and requires a more powerful fuse. Like dynamite, it may be used under water.

It was used with success by the engineers in the Philippine Islands.

Guncotton. Guncotton, moistened with 15 to 30 per cent of water, burns slowly if held in a flame or thrown into a fire; it cannot be ignited or exploded by percussion or friction; a rifle ball tears it to pieces without igniting it; it may be handled, sawed or cut with safety; its chemical organization is unaffected by frost.

Although in the wet state it can be detonated only by an abnormally strong detonator, it can be detonated readily if a small primer of dry guncotton is placed in close contact with it.

It may be safely stored and transported, if preserved from light.

Dry guncotton burns readily, and in a confined place the temperature may rise to the point of detonation; it may be ignited by percussion, but a rifle ball will only tear it to pieces, setting fire to the fragments.

The poisonous fumes produced by the detonation of guncotton make it an undesirable explosive in mining or similar work.

Guncotton is the explosive adopted in the British service, where it is formed into primers of 1 ounce, and into slabs of about 1 pound.

The primers are kept dry and coated with beeswax; they are stored in hermetically sealed cylinders each containing 10 primers.

The slabs are stored and carried into the field soaked with 20 to 30 per cent of water. Each is packed in a sealed, tinned box placed in an outer box of wood.

Guncotton is not manufactured to any considerable extent in this country and would not, at present, be available for military purposes.

Picric-acid Compounds. In the form of *mélinite*, this explosive is used in the French service; and in the form of "*explosive* 88," it is used in the German service. It is claimed for these explosives that they are as safely handled as guncotton, and are more stable if kept from contact with lead, copper and calcium.

In the French service, mélinite is formed into *cartridges* of $3\frac{1}{8}$ ounces, and into *petards* of 5 ounces and 2 pounds.

In the German service, shell-filling compound is formed into *cartridges* of 2 pounds. The cartridges are inclosed in a tin case.

Methods of Igniting Charges. The ordinary method of igniting a charge of powder or high explosive is by means of a *safety fuse* and *detonator* (Plate XXIII, Fig. 1).

A *safety fuse* is a train of powder inclosed in a flexible wrapping of hemp or cotton which is made water-proof when used in damp places or in submarine work. The usual rate of burning is about 3 feet per minute.

An *instantaneous* fuse which burns at the rate of 30 yards per second is manufactured for use in producing

simultaneous explosions. The various charges to be exploded are connected by equal lengths of instantaneous fuse spliced to the end of a piece of ordinary safety fuse.

A *detonator* is a cylindrical copper cap partially filled with fulminate of mercury.

The end of the safety fuse is cut square and made to fit the detonator by paring the coating or by wrapping it with paper. It is inserted in the detonator until it touches the fulminate, and is fastened there by crimping the copper tube, either with a special pair of pincers or with the back of a knife.

The detonator is inserted in holes which are left for it in the slabs of guncotton and picric-acid compounds, but may equally well be tied to them.

In the ordinary dynamite cartridge, the top of the cartridge is opened and a hole is carefully made with a wooden rod. The detonator is inserted into this hole, and the paraffined paper is drawn closely around the safety fuse and tied with a string (Plate XXIII, Fig. 2).

To prevent the detonator from being torn out of the cartridge, the safety fuse may be wrapped around it.

If several cartridges in close contact are exploded, the detonator need only be placed in one.

Detonators should never be stored or transported with high explosives.

For igniting gunpowder a train may also be made of a strong linen tube filled with powder; this is called a *powder-hose;* the hose may be protected by inclosing it in a wooden trough, called a *hose-trough.*

Electricity may be employed in detonating high explosives, or in igniting gunpowder. For this purpose an *electric fuse* is used instead of the simple detonator.

The fuse consists of a *tube A, fulminate charge B, fuse plug* or *cement C, insulated conductors D,* and *platinum bridge E* (Plate XXIII, Fig. 3).

Electric fuses, like detonators, must not be stored or transported with high explosives.

Insulated wires connect the fuse with the generator; joints in these wires are made by baring the ends of the conductors and then twisting the wires together. At the generator the bared wires are inserted in the binding-posts.

The *generator* usually employed in mining, blasting and demolitions is the Laflin-Rand Magneto-Exploder No. 3 (Plate XXIII, Fig. 4). It is a small portable dynamo inclosed in a box which measures 5×16 inches; it weighs 18 pounds and may, under favorable circumstances, be used to explode ten fuses arranged in series.

Formulas. The following empirical formulas are given in the Chatham course in military engineering. They were deduced from experiments made with guncotton, but will apply equally well to dynamite No. 1. If the weaker forms of dynamite are used the charges must be correspondingly increased.

The formulas are given for high explosives untamped; the charge may be decreased about one-half if well tamped. They may be used for well-tamped gunpowder if the charge is doubled.

Timber. $C = \frac{3}{5}T^2$, if the charge is placed in one or more holes bored in the same plane of cross-section.

$C = 3T^2$ if the charge is arranged as a necklace. C = charge in pounds, T = thickness in feet.

The first formula was tried at West Point with 60 per cent dynamite and was found effective without tamping; better results were obtained, however, when the hole behind the charge was tamped with clay. The second formula did not give sufficiently large charges with 60 per cent dynamite.

Wrought-iron or Steel Plates. $C = \frac{3}{2}Bt^2$. C = charge in pounds, B = breadth in feet, t = thickness in inches. The cartridge must extend entirely across the plate.

Other authorities give the charge for I-beams as $\frac{1}{8}$ of a pound per square inch of cross-section for small beams, and $\frac{3}{8}$ of a pound per square inch for large ones.

Steel-wire Cable. The charge for destroying an ordinary steel-wire cable is 1 pound.

Masonry. $C = \frac{3}{4}BT^2$ for brick arches; $C = \frac{1}{2}BT^2$ for brick walls. C = charge in pounds, B = length of breach in feet, T = thickness of wall in feet.

Field and Siege Guns. Two pounds of explosive, placed in the bore and tamped with sand, will destroy a field gun.

Applications. Trees may be felled by placing the charge in radial holes bored for the purpose, or by arranging the charge as a necklace around the tree if less than a foot in diameter (Plate XXIII, Figs. 5 and 6).

Timbers may be treated in a similar manner, or the charge may be laid across one side (Plate XXIII, Fig. 7).

Stockades, palisades, etc., are destroyed in the same manner as trees; the charges are placed in holes bored in the timber, or are simply laid against the foot of the stockade or palisade and well tamped with earth.

Iron beams and girders, if small, are destroyed by placing the charge between the flanges; if large, by placing the charge entirely around the beam or girder (Plate XXIII, Figs 8 and 9).

A girder is difficult to destroy with explosives; it is usually better to attack the piers or abutments of a girder bridge, or to use levers and throw the bridge from its supports.

Framed structures are destroyed by attacking their most essential parts. In a pin-connected or rivetted truss these are the two chords.

Suspension bridges are destroyed by attacking the main cables near the anchorages.

Piers are treated as thick walls, the charges being concentrated in a few chambers.

Segmental arches are ruptured by placing charges above or below the crown (Plate XXIII, Fig. 10).

In full-center arches the charge may also be placed above the haunches.

A lined tunnel is treated as an arch, and the charge is placed in rear of the lining at the haunches. In an unlined tunnel, chambers are excavated in the side of the tunnel where the stratification indicates that the greatest amount of damage can be done.

Roadways, in a mountainous country, are destroyed by placing charges behind the side slopes and retaining-walls (Plate XXIII, Fig. 11).

The walls of a house are treated as ordinary masonry walls, or a charge of powder is placed in the center of a ground-floor room, and struts are arranged to connect the side walls and the charge, so that the explosion will force out the walls. This may also be effected by tightly closing all doors and windows, and exploding a large charge in the interior.

Railroads. The attack upon a railroad system may be directed against its rolling-stock, its bridges, its tunnels, or its roadway.

Locomotives are rendered temporarily useless by the removal of valves, connecting-rods, etc.; they are permanently disabled by detonating a charge of explosive in the boiler, or by burning out the flues.

The rolling stock is burned, or it may be broken up, either in collisions or by running trains over embankments.

Bridges and tunnels are usually destroyed by explosives, as explained above.

Long and high bridges and tunnels are the easiest part of a railway to destroy, and the most difficult parts to replace or repair.

Around railroad stations the frogs of switches are destroyed by explosives wedged between the rails.

In the Civil War, when it was desired to render a portion of the track temporarily useless, a company equipped with levers was distributed in a line along a section of the track. The ties having been loosened and the fish-plates at the end of a section removed, at a

command the track was lifted up on one side and tipped over. Two men were usually detailed to each tie.

To destroy the tracks permanently, the rails were afterwards loosened from the ties with sledge-hammers and crowbars, and the ties were collected in piles of 50 to 80, and burned. The rails were thrown upon the burning ties and, when red hot, were bent by loading their ends, or were twisted by using cant-hooks or by wrapping them around a tree or telegraph post (Plate XXIV, Figs. 1 and 2).

Telegraph Line. A telegraph line may be temporarily disabled by skilfully placing "faults" in it. These are breaks, leaks and contacts.

A *break* is a disconnection in a conductor; a *leak* is a ground connection attached to the conductor; a *contact* is a wire connecting two or more conductors. These should be so placed as to be concealed from anyone casually examining the line.

To destroy the line, the wires after being removed from the poles are twisted together, and the poles are cut down and burned.

CHAPTER X

COMMUNICATIONS

In modern warfare railroads and water transportation are relied upon to mobilize an army, to transport it to the theater of operations, and to bring its supplies from the base of operations to the advance field base.

The movement of the army in the theater of operations, and the transportation of its supplies from the railway and river depots to the different commands, are over the ordinary roads of the country, supplemented by such others as the army may have time to construct.

The general study of the communications in any proposed theater of operations belongs to the domain of strategy; the care and improvement of the railways are usually the province of a special branch of the Engineer troops, but all other troops may be called upon to improve the condition of the roads over which they are to march, so that there may be no unnecessary delays in military movements.

In our army in the Civil War, the duty of repairing the roads fell upon the pioneer detachments which were organized in every infantry division in the Army of the Potomac, and in every army corps in the western armies.

Classes. Roads may be roughly classed into *paved, macadamized, gravel* and *earth* roads.

A good paved road has a wearing surface of some such material as *stone, brick, wood,* or *asphalt,* and a foundation of *concrete.*

A macadamized road has a wearing surface of small broken stone covered with stone-dust, gravel or clay,

and a foundation of larger broken stone either thrown in at random, or set on edge.

A gravel road has a wearing surface of small gravel, and a foundation of coarse gravel.

An earthen road has no distinct wearing surface or foundation; it is made by throwing up a slight embankment of soil and compressing it by travel.

Requisites of a Good Roadway. The wearing surface should be *smooth, hard* and *impenetrable to water;* the foundation should be *firm* and *unyielding,* so as to carry the travel without allowing any deformation in the wearing surface; the drainage should be such as to allow no water to remain either upon the wearing surface or in contact with the foundation of its bed.

Repairs. The maintenance of a roadway in good condition demands that proper attention be given to its wearing surface, its foundation and its drainage.

Existing paved and macadamized roadways require little attention from the military authorities.

It is occasionally necessary to replace some of the culverts and bridges which have been destroyed by the enemy, or to strengthen others which are too weak to carry siege artillery and heavy supply wagons.

A gravel road is in good order if it is properly drained, and if it consists of a bed of good gravel at least 8 *inches* thick.

If the gravel contains too large a percentage of clay, the road will be in good condition during dry weather, but will be almost impassable in continued wet weather. Particular attention must be paid to the thorough drainage of such a road, and in wet weather repairs must be made with gravel containing sand, or with clean gravel from a river-bed.

If no sandy gravel is obtainable, brush is carefully placed on the road to protect it from the formation of ruts.

If the gravel used in the construction of a road is entirely

free from clay or loam, the road becomes loose and wears away rapidly in dry weather. It may then be improved by a thin coating of gravel containing clay or loam.

Earth roads are similar to gravel roads, but deteriorate more rapidly under unfavorable conditions.

If the soil is clay, every precaution should be taken to drain the road thoroughly, otherwise it will soon wear into deep ruts.

In wet weather it should never be repaired by adding material containing clay, but always by adding material containing sand.

If the roadway is naturally sandy, thorough drainage is not essential, but in dry weather a little loam should be added to bind the sandy particles.

Drainage. All overhanging trees and brush which prevent the rays of the sun from reaching the roadway should be removed. Evaporation thus assists the drainage.

The cross-section of the wearing surface should be made the arc of a circle or two planes connected by the arc of a circle, and the crowning of the road should be increased with the softness of the material in this surface; this prevents water remaining upon the roadway.

Side ditches, cross-drains and culverts should be provided to carry off rapidly all surface and subsoil water, so as to keep the soil upon which the road is constructed as dry as possible.

Side ditches are open trapezoidal ditches 2 or 3 feet deep, which are usually constructed upon both sides, just outside of and parallel to the roadway.

Roads constructed along the slope of a hill need but a single ditch, which is on the side next to the hill; the surface of the road should slope from the outside towards this ditch.

In a cut, unless the side slopes are protected by revetments, the side ditches are rendered useless by the crumbling slopes, which rapidly fill them with soil; to obviate this defect use should be made of blind drains.

A *blind drain* is a small culvert covered with material which allows the water to percolate through it readily. The drain may be made of tile with open joints, of two or more longitudinal logs or fascines, or of rows of stone, covered with brush or broken stone. (Plate XXIV, Figs. 3 and 4.)

If the subsoil is very wet, one or more such blind drains should be constructed under the roadway itself, either parallel to the side drains or oblique to them. (Plate XXIV, Fig. 5).

Cross-drains are especially essential in roads running along the face of a hill (Plate XXIV, Fig. 7); they may be shallow paved gutters, blind drains or open culverts, depending upon the amount of water they are to carry, and the difficulty of making excavations.

The first form is also useful in catching the water which flows in the wheel tracks down long, steep slopes.

Culverts are usually made of sewer or iron pipe, of planks, of logs, or of rough stone masonry. The minimum cross-section of a culvert of planks, logs or stone is usually 2 feet square.

A culvert should never be constructed in a new embankment, but should be located in the solid ground either at the bottom, or in one of the slopes of the depression in which it is constructed.

In swampy regions it is frequently impossible to drain the roads; in such localities an ordinary road is repaired by converting it into a corduroy or plank road.

During the Civil War *corduroy roads* were made by laying a foundation of longitudinal stringers with intervals of 4 feet. These were covered with poles averaging 7 inches in diameter which were placed in close contact.

The wearing surface was made by filling the interstices with small sticks and covering the whole, first with brush and then with earth. In many instances the covering of brush and earth was omitted, and the cross-pieces were held in place by side rails spiked to them.

Plank roads are made of thick planks either spiked to the stringers or held in place by side rails. The planks replace the round sticks in ordinary corduroy construction.

Wherever the road is wholly or partially below the adjacent ground, a ditch should be cut at some distance from, and parallel to the road, to catch the surface water before it reaches the road (Plate XXIV, Fig. 7).

Embankments. In repairing roads in a mountainous region, it is often necessary to construct retaining walls to support the road.

These are usually made of dry stone masonry with a batter 5/1, or of logs in the form of crib work (Plate XXIV, Fig. 7).

New Roads. New roads, constructed by troops in the field, must be made with a minimum expenditure of time and labor; these requirements forbid any extensive grading.

Since the maximum grade on a road should, if possible, never exceed 6 per cent, or 6 feet in 100, a route must be selected on which the maximum grade can be secured without much labor. A reconnaissance with a hand level will usually determine the route.

The road is located on the ground by driving pegs or stakes, every 100 or 200 feet, to indicate the center line.

As soon as the location is fixed, working parties begin to clear the roadway of trees, brush and boulders, and to construct bridges and culverts wherever necessary.

The road is then brought to grade, and is completed by giving it proper drainage, and a wearing surface of the best material which can be found in the vicinity.

Marking Roads. Columns of troops often go astray, particularly at night, if the road to be followed is not carefully marked wherever the road forks or is intersected by other roads.

The road to be followed may at these points be clearly indicated on fences, trees, stones, etc., by the use of paints,

crayons or pieces of cloth, etc., or by blocking the other roads with rails, trenches, mounds, etc.

At night lanterns or pieces of white cloth must be used.

Trails through woods are indicated by blazing the trees along the trail.

The line of a ford to be followed may be indicated by poles with flags for daylight crossing, and by lanterns at night.

Hooded lanterns, which conceal the light from positions in front, may be employed to guide columns moving at night in the presence of the enemy. They are placed by scouts sent in advance of the column.

APPENDICES

APPENDIX A.

TABLE INDICATING THE NUMBER OF MEN, TOOLS, AND THE TIME NEEDED FOR EXECUTING FIELD FORTIFICATIONS.

Classification.	Number of Men in Working Party.	Hours.	Average Task per Hour per Day's Work	Tools.	Material.	Remarks.
Brush (bundles).	8	1	8	8 bill-hooks or hatchets	Brush, 1″ to 2″ at butt	Weight of bundle, 50 lbs. each.
Fascines.....	6	1	1	1 trestle, 1 fascine-choker, 3 bill-hooks, 1 hatchet, 1 hand-saw, 1 pair pincers, 1 measuring-rod, 1 mallet.	Per fascine, 3 bundles of poles, 12 binding withes or wires,	Poles about 2″ at butt. Weight of fascine, 150 lbs.
Gabions (brush).....	6	1	1	2 gabion-forms, 2 hatchets, 2 bill-hooks, 2 pair pincers, 2 measuring-rods, 2 lashings 5 ft. long, 2 hand-saws, 2 mallets.	Per gabion, 1 bundle-brush, 9 stakes, 9 binding withes or wires,	Weight of gabion, 36–56 lbs.
Gabions (wrought-iron)..	3	1	1	1 riveting-hammer, 1 cold chisel.	Per gabion, 10 stakes, 220 ft. hoop-iron, 70 rivets.	
Hurdles.....	3	2½	1	2 hatchets, 2 bill-hooks, 1 mallet, 1 hand-saw, 1 measuring-rod.	Per bundle, 1 bundle-brush, 10 stakes,	Hurdles are 6 ft. long, wt. 56 lbs.
Palisades(making panels)	24	1	7	5 axes, 4 hand-saws, 4 hatchets.	Per panel, 4 posts, 9 lin. ft. of 2″ planks, 1¾ lbs. 6″ spikes.	4 axe-men; 12 carriers; 4 men to saw and sharpen; 4 men to make and pile panels; 4 posts and 2 cleats to each panel, 4″ to 7″ diameter.
Pickets.	1	1	25	1 hatchet.		25 in one bundle.
Stakes.....	10–12	1	100–150	2 axes, 4 hatchets, 3 hand-saws, 1 measuring-rod.		2″–3″ at butt, 6 ft. long.

Classification.	Number of Men in Working Party.	Hours.	Average Task per Hour for Day's Work	Tools.	Material.	Remarks.
Trees (cutting up).....	2	1	12″–6″ or 6″–12″	2 axes, 1 cross-cut saw, 1 measuring-rod.		
Trees (felling).....	2	1	do.	2 axes, 1 cross-cut saw.		
Wire (anchoring ties).....	2	1	60	wire-cutter or hatchet.	160 yards wire,	Telegraph wire.
Withes (anchoring).....	2	1	12	2 bill-hooks,	½″ to ¾″ diameter.	
Withes (binding).....	1	1	12	1 bill-hook,	do.	
EXCAVATION.						
Earth excavation.....	1	1	1 cu. yd.	1 spade,	Light soil,	1-hour tasks.
" "	1	1	¾ " "	1 spade, 1 pick,	Medium soil,	
" "	1	1	⅓ " "	do.	Hard soil.	
" "	1	1	¾ " "	1 spade,	Light soil,	Average of 4-hour tasks.
" "	1	1	½ " "	1 spade, 1 pick,	Medium soil,	
" "	1	1	¼ " "	do.	Hard soil.	
TRENCHES						
Shelter-trench, Pl. I, Fig. 1....	1	⅓	1 lin. yd.	1 spade,		
" " Pl. I, Fig. 2....	1	⅔	1 " "	1 spade, 1 pick,		
" " Pl. I, Fig. 3....	1	1⅓	1 " "	1 shovel, 1 pick,		
" " Pl. I, Fig. 4....	1	4	1 " "	1 shovel, 1 pick,		
" " Pl. I, Fig. 5....	1	3 7/12	1 " "	1 shovel, 1 pick.		
" " Pl. I, Fig. 6....	2	4	1 " "	2 shovels, 2 picks.		
" " Pl. II, Fig. 8...	8	8	1 " "	6 shovels, 2 picks.		

APPENDIX A.—*Continued.*

OBSTACLES.

Classification.	Number of Men in Working Party.	Hours.	Average Task per Hour per Day's Work	Tools.	Materials.	Remarks.
Abatis	18	1	1 linear yd. in 3 rows,	2 axes, 2 hand-saws, 2 cross-cut saws, 2 picks, 4 spades, 2 mauls,		3 squads.
Entanglements (low wire)	10	1	9 linear yds	2 mauls, 4 wire-cutters, 4 picks, 4 hatchets. 1 measuring-rod,	Per linear yard, 1⅓ stakes, 2⅔ yards wire,	10 yards wide.
Entanglements (high wire)	10	1	3 linear yds.	2 mauls, 4 wire-cutters, 4 picks, 4 hatchets, 1 measuring-rod,	Per linear yard, 2 stakes, 8⅓ yards wire,	10 yards wide; without barbed horizontals and stakes placed in advance.
Entanglements (high wire)	10	1	1⅓ lin. yds.	2 mauls, 4 wire-cutters, 4 picks, 4 hatchets, 1 measuring-rod,	Per linear yard, 2 stakes, 9⅔ yards wire,	10 yards wide, with barbed horizontals and stakes placed in advance.
Palisades (erecting panels)	10	1	6	4 spades, 2 picks, 2 rammers,	6 panels,	4 men can carry panel; 6 panels = load for 4-horse team; distance = 50 yards.
Pickets (small)	10	1	2 sq. yds.	3 hatchets, 2 hand-saws, 2 garden-trowels, 2 mauls,	Per square yard, 9 pickets,	
Slashings	10	1	3 linear yds.	8 axes, 2 cross-cut saws,		4 rows deep.
Trous-de-loup	10	1	1 linear yd.	4 spades, 2 picks, 2 hand-saws, 2 hatchets, 1 maul,	50 stakes,	7 rows.

APPENDIX A.—*Continued.*

REVETMENTS.

Classification.	Number of Men in Working Party.	Hours.	Average Task per Hour per Day's Work	Tools.	Materials.	Remarks.
Brush	6	1	3 sq. yds.	2 axes, 2 spades, 2 hatchets, 1 maul, 1 cross-cut saw, 2 bill-hooks, 1 pair pincers,	Per linear yard, 3 stakes, 1 anchoring-wire, Per square yard, 1½ bundles brush	
Fascine (putting in place)	6	1	3 sq. yds.	2 spades, 2 hatchets, 1 mallet, 1 pair pincers,	Per square yard, 7 pickets, 3 anch'ing-stakes 3 anch'ing-wires,	
Gabion	4	1	15 sq. yds.	2 shovels, 1 pick,		Without anchorages.
Hurdle	6	1	5 sq. yds.	2 spades, 2 hatchets, 1 pair pincers, 1 maul,	Per 5 sq. yds., 3 hurdles, 9 stakes, 9 anch'ing wires,	Hurdles previously constructed.
Plank	6	1	4 sq. yds.	2 axes, 2 hatchets, 2 hand-saws, 1 maul, 2 spades,	Per square yard, 10 ft. B. M. planks 1 post, 1 anchor,	
Sand-bags (filling)	6	1	160	2 shovels, 1 pick,	160 bags,	
Sand-bags (placing in revetment)	2	1	160			100 square feet revetment.
Sod (cutting)	3	1	160	1 spade, 1 line,		Sods 18″ x 8″ x 4″ = 3 sq. yds.
Sod (placing in revetment)	3	1	3 sq. yds.	Pegs,	160 sods.	

APPENDIX B

THICKNESS OF SHIELD TO RESIST MODERN FIRE

German Regulations

1 meter = 3.28 feet = 39.36 inches.

RIFLE FIRE	METERS	REMARKS
Broken stone	0.15	
Sand or gravel in bags	0.40	
Earth	0.50 to 1.00	
Snow	1.50 to 3.00	
Pine	0.65 to 0.90	according to range
Oak	0.55 to 0.70	" "
Cast-iron	0.15	
Steel	0.08 to 0.12	
Brick masonry	0.25	against single shot
"	0.50	" continued fire
MACHINE GUN		
Earth	1.00	at 100 yards (considerable increase for shorter ranges)
FIELD GUN, SHRAPNEL AND SHELL		
Earth	0.40 to 1.00	
Wood	0.08	
Brick masonry	0.25	
FIELD HOWITZER, SHRAPNEL AND SHELL		
Earth	1.00	
Wood	0.16	
Earthen cover of wooden roof	0.30 to 0.50	
Brick masonry	0.25	
Railroad rails		single layer
Broken stone between beams	0.25	
FIELD GUN, SINGLE DIRECT SHOTS		
Earth	2.00	
Brick masonry	1.00	
Snow	8.00	
FIELD HOWITZER, DIRECT SHOTS (Flat trajectory)		
Earth	3.00	
Brick masonry	2.00	
Concrete masonry	1.00	
(Curved trajectory against roofs)		
Earth combined with railroad rails or heavy beams	2.50	
Brick masonry	0.90	
Concrete masonry	0.70	

APPENDIX B—*Continued*

PENETRATION OF .30 CALIBRE RIFLE BULLET IN VARIOUS SUBSTANCES AT 500 YARDS RANGE, FRANKFORD ARSENAL, 1894.

(In tests with oak and pine the penetrations were in all cases transverse to the fibres.)

Material.	Penetration (inches).	Mean Penetration (corrected; inches).	Remarks.
Oak, green, not of best quality.	4 inches oak and 7 one-inch boards of pine butt; 4 inches oak and 4 one-inch boards of pine butt; 4 inches oak and 7 one-inch boards of pine butt; 6 inches oak and 4 one-inch boards of pine butt; 6 inches oak, point through oak 0.25 inches; 6 inches oak, point through oak 0.125 inches.		
	6.5 inches oak.....	Oak, 6.5	Penetration in 12-inch block.
	6.5 inches oak		
	6.5 inches oak		
Pine, soft, "white," green, not of best quality.	16 inches solid pine block and 3.25 one-inch boards of pine butt; 16 inches solid pine block and 3.25 one-inch boards of pine butt; 16 inches solid pine block and 2.25 one-inch boards of pine butt; 20 inches solid pine block, point projected 0.5 inch; 18 inches solid pine block 20 inches in thickness; 18.5 inches solid pine block 20 inches in thickness.		
	21.6 21.8 21.6	21.66	Through one block 20 inches in thickness and into second block in close contact. In the latter penetrations (21.66 inches) the blocks were greener and contained more moisture than was the case in the experiments with pine blocks first recorded.
Brick wall 9 in. thick, 25 by 21.5 inches.	1.25 1.375 1.375 4.+	1.33	This section was made double of "dark stretcher" or ordinary building-bricks. The wall was allowed to dry after laying for a period of about two weeks, but in examination made after firing to determine the effects, the mortar was found to be still somewhat "green" and soft. Struck joint and passed through to brick in rear. The bricks struck were cracked and shattered about the point of striking, triangular pieces being broken out, which allowed the bullets to change direction and pass into the joints. A concentrated and well-directed fire

APPENDIX B.—*Continued.*

PENETRATION OF .30 CALIBRE RIFLE BULLET IN VARIOUS SUBSTANCES AT 500 YARDS RANGE, FRANKFORD ARSENAL, 1894.

(In tests with oak and pine the penetrations were in all cases transverse to the fibres.)

Material.	Penetration (inches).	Mean Penetration (corrected; inches).	Remarks.
Brick wall 9 in. thick, 25 by 21.5 inches.	1.25 1.375 1.375 4.+	1.33	would probably soon make an opening through a wall so constructed. The bullets were found, as a rule, in the joints, but the last was apparently the only one that struck a joint fairly.
Sand, moist....	18.0 18.0 18.0	18.5	In obtaining penetrations in the different kinds of earth, the pine butts were placed in position in rear to provide for cases of complete perforation of the earth, but in all cases it happened that the thickness of the latter was sufficient to arrest the bullet. Additional tests will be made in accordance with your directions, as opportunity offers, to obtain a record of these mixed penetrations.
Loam.....	22.0 22.0 25.0	23.64	
Coarse gravel..	12.0 12.0 11.0 11.0	11.8	
Sand and loam, one-half each	17.0 17.0 21.0	18.8	
Clay.....	22.0 22.0 22.0	22.6	
Clay and loam, one-half each	22.0 22.0 22.0	22.6	

In the case of sand, clay, etc., increase of one thirty-sixth is made as "correction" to allow for the half-inch pine board used to retain above. This correction is based upon the penetration at 500 yards of 18 one-inch pine boards, these being separated by spaces of one inch. The sand, clay, etc., were placed in a trough having a cross-section about 2 feet square, and allowed to settle simply by the pressure of their own weight.

Report of Chief of Ordnance, 1895.

APPENDIX B—*Continued*

PENETRATION OF UNITED STATES RIFLE

Caliber 30, model of 1903

	Penetration in Inches.			
	50 ft.	100 yds.	500 yds.	1000 yds.
White pine butts made of 1-inch boards placed 1 inch apart	59.98	52.80	26.36	10.48
Moist sand	10.06	14.02	16.1	13.9
Dry sand	6.32	6.88	13.12	10.86
Loam practically free from sand	19.9	17.46	23.62	17.46
Thoroughly seasoned oak across the grain	34.19	31.18	14.33	
Brick wall	.....	5.5		
Low steel (boiler plate)	0.53	0.40	0.01	0.00

APPENDIX C

INTRENCHING TOOLS OF U. S. ARMY

INFANTRY

Carried by troops. (*G. O.* 23, 1906)

Each company of infantry or other troops serving as infantry will be equipped with intrenching tools, as follows:

1 two-foot rule.
3 wire cutters.
4 hand axes.
1 pick mattock for each squad.
3 shovels for each squad.

The two-foot rule, hand axes, and wire cutters are constant per company and are carried by the sergeants and musicians. The pick mattocks and intrenching shovels vary with number of squads and are carried alternately by the members of the squads.

Carried in wagons. (*G. O.* 221, 1907)

To each company:

Auger, 1-inch	1	Pliers, wire-cutting	7
Axes	6	Rule, 2-foot	1
Crowbar, 12 pounds	1	Saw, hand, cross-cut, with sheath	1
Hatchets	6	Rope, 2½-inch, feet	250
Machetes, with sheaths	20		

All articles for companies of infantry will be furnished by the Engineer Department. The equipment of the twelve companies will be carried on a single extra regimental wagon.

CAVALRY

Carried on pack animals. (*G. O.* 221, 1907)

To each troop:

Auger, 1-inch	1	Pliers, wire-cutting	6
Axes, 6-pound	4	Rules, 2-foot	2
Crowbar	1	Saw, cross-cut, with sheath	1
Hatchets	4	Shovels, large	15
Pick mattocks, large	5		

Demolition Outfit

To each squadron:

Box, match, tin	1	Fuse, instantaneous, feet	200
Caps, detonating	100	Hammers, drilling, 7-pound	2
Chisel, cold, 1½-pound	1	Hammer, engineer's, 3-pound	1
Crowbars	2	Pliers, nose-cutting	1
Drills, double-bitted	2	Spoon, drilling	1
Explosive, pounds (racka-rock)	50	Wrench, monkey	1
Fuse, Bickford, feet	200		

MACHINE-GUN PLATOONS

For each machine-gun platoon. (*G. O.* 213, 1906)

Rule, 2-foot	1	Pick mattocks	2
Wire cutters	2	Shovels, large	6
Hatchets	2		

One platoon to each regiment of cavalry and regiment of infantry.

FIELD ARTILLERY

Carried by the vehicles

Axes	30	Picks	18
Hatchets	18	Shovels	35
Mattocks	12	Crowbar	1

Blacksmith's and carpenter tools.

ENGINEERS

Each company of Engineers has two wagons and four pack-mules for the express purpose of carrying equipment similar to the above, which is quite extensive and which varies according to the character of service likely to be required.

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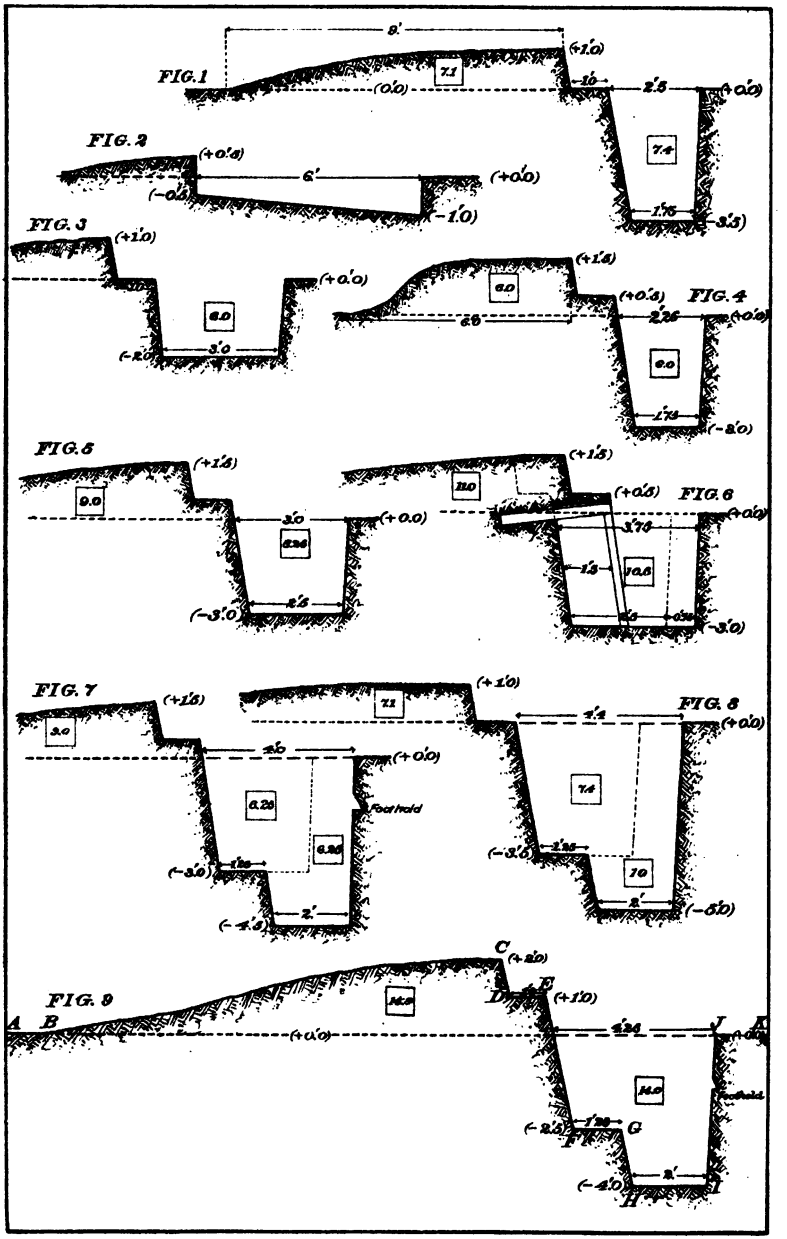
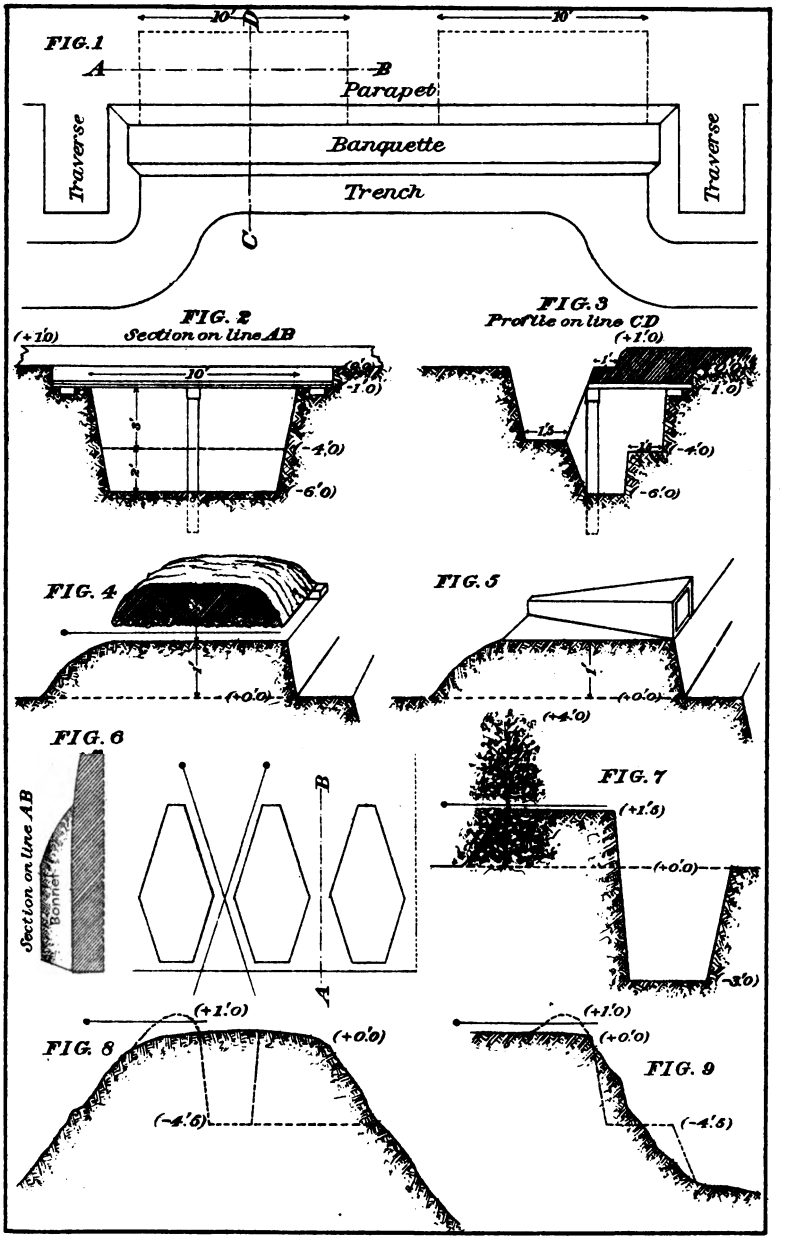
PLATE I.





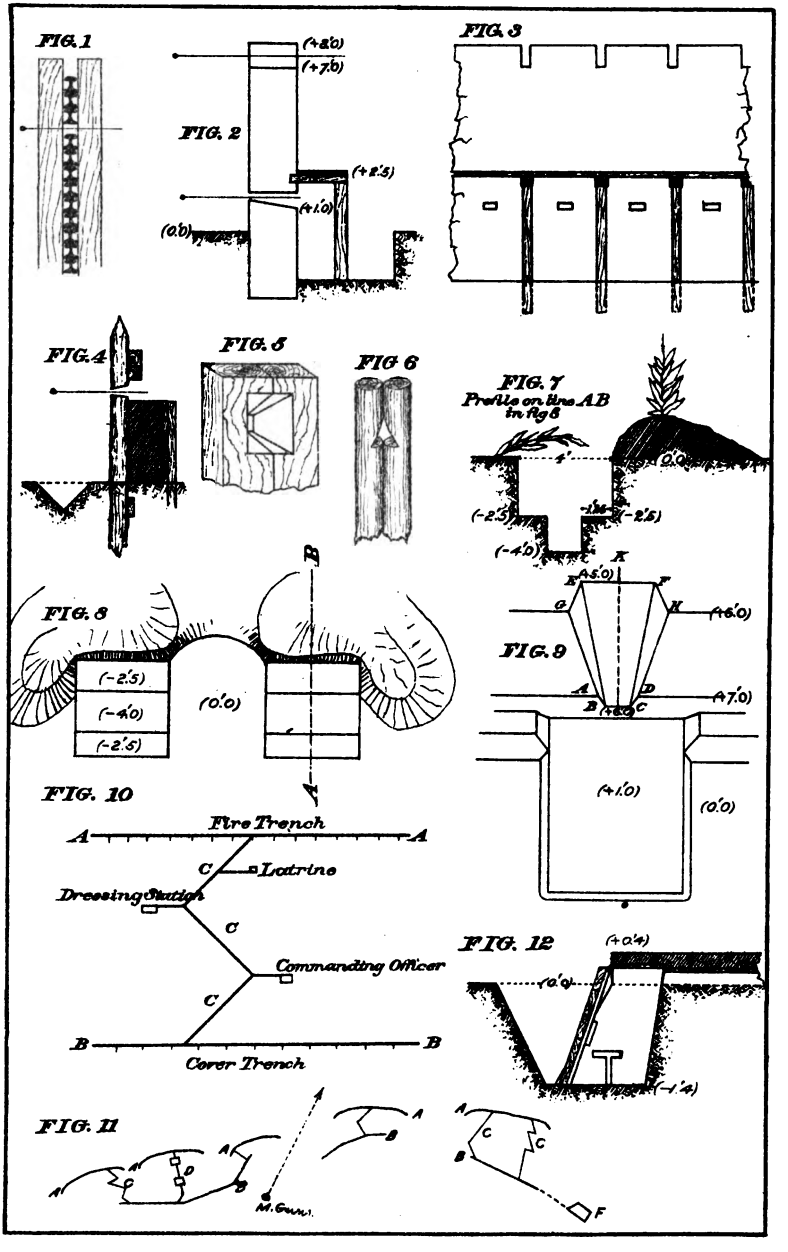


PLATE IV.

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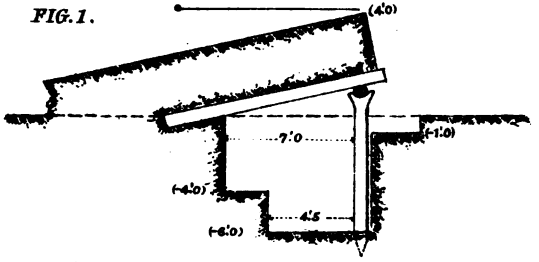

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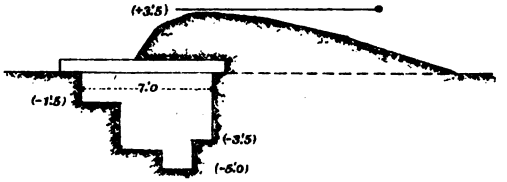

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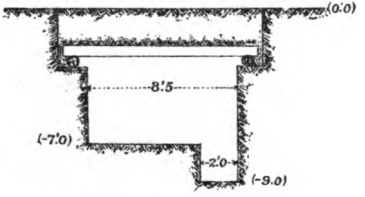

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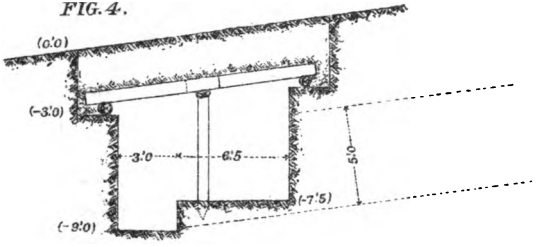

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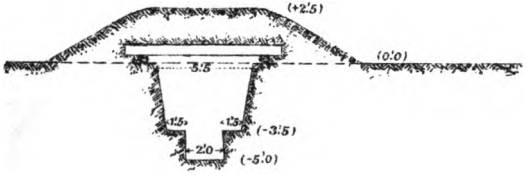

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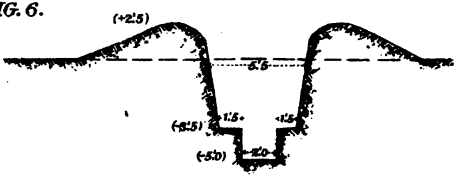

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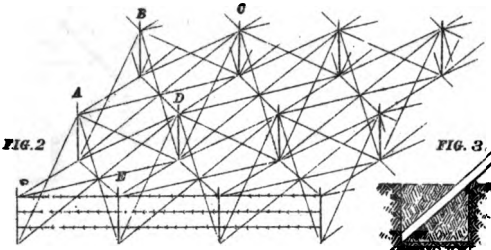

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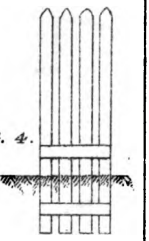

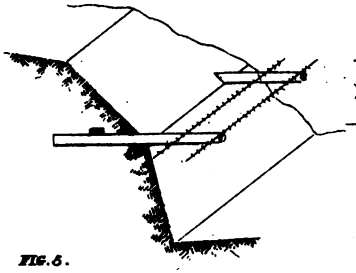

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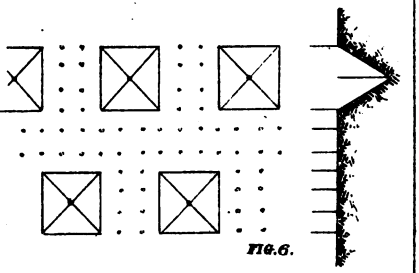

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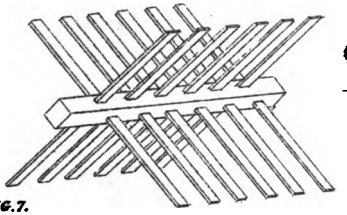

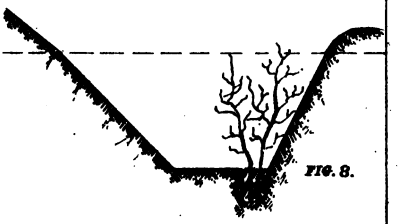

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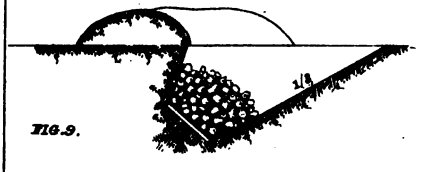

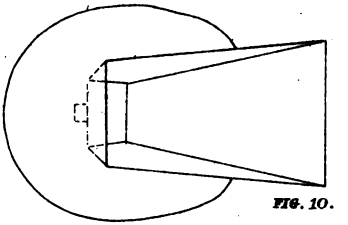

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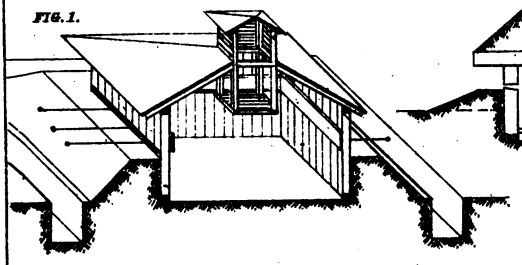

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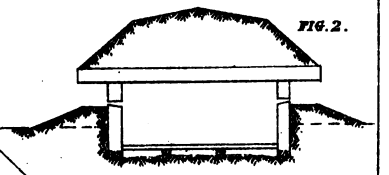

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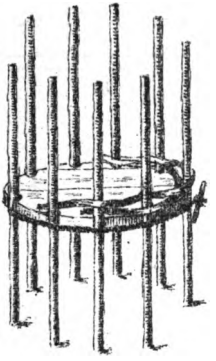

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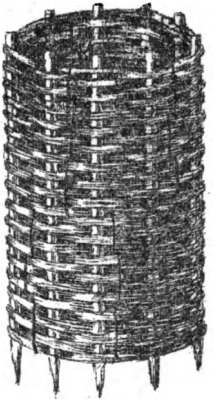

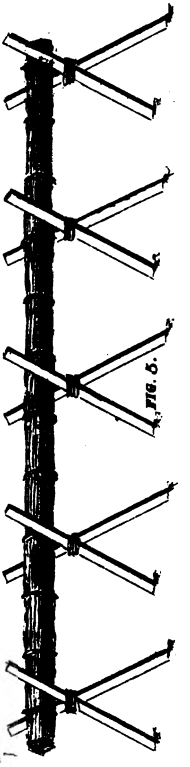

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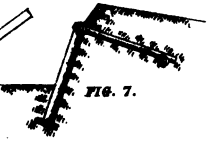

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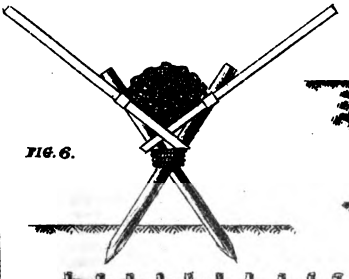

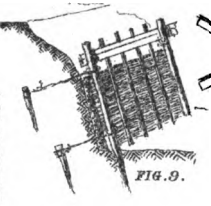

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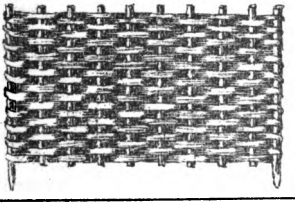

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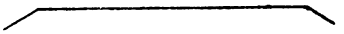

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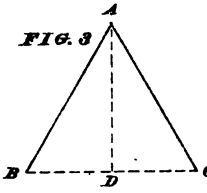

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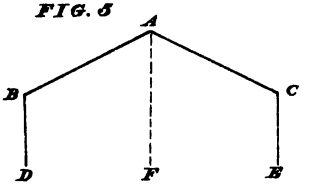

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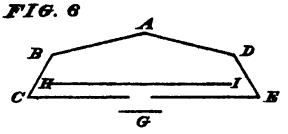

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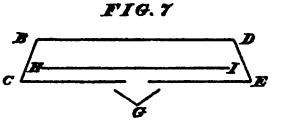

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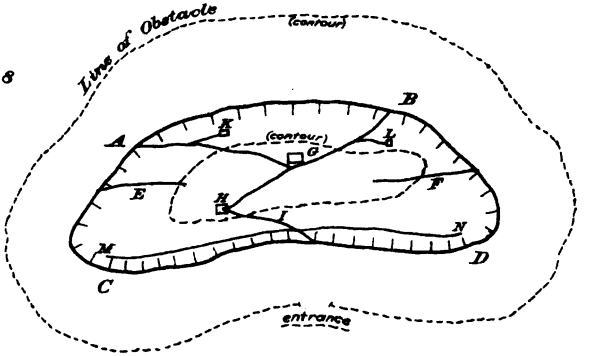

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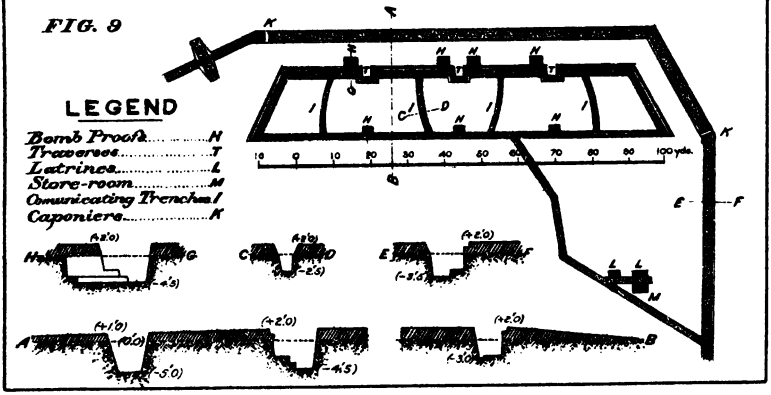


PLATE VIII

Russian redoubt near Shanlantzu on the Sha River, Manchuria.

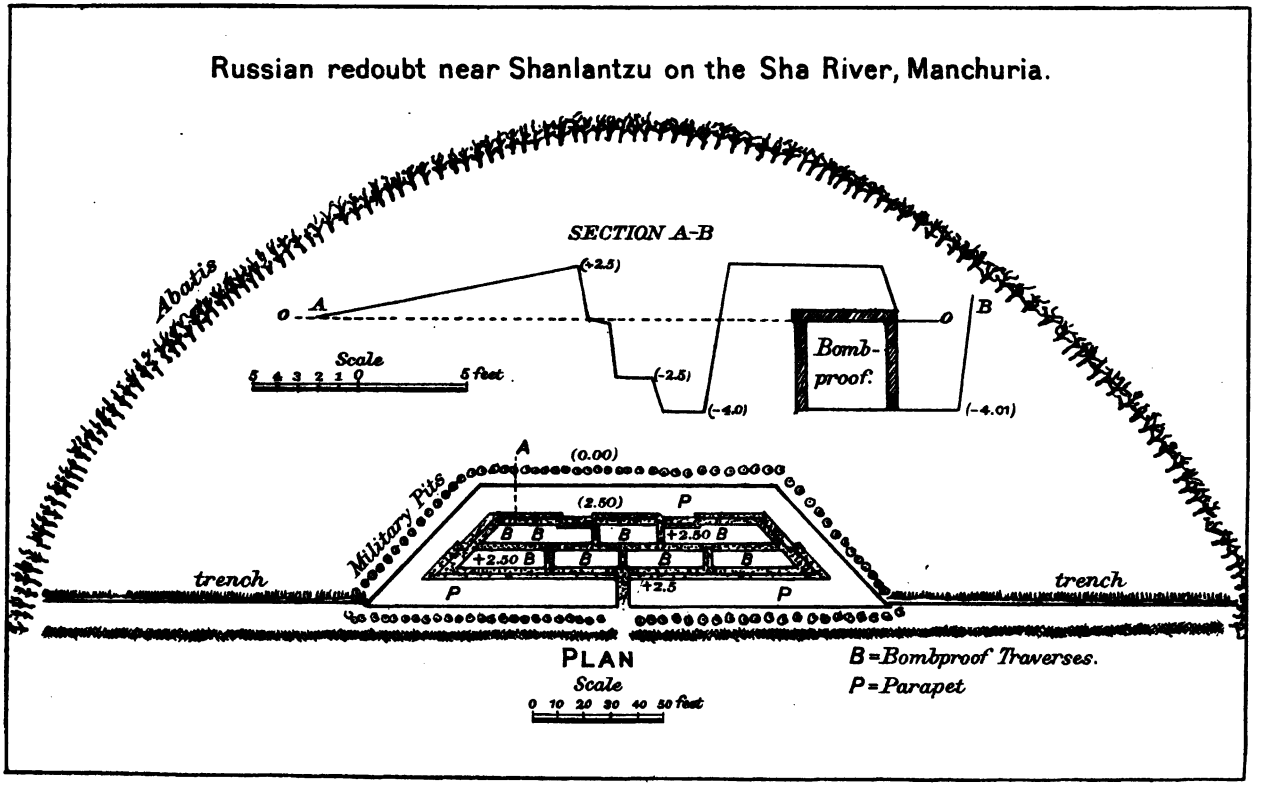


PLATE IX.

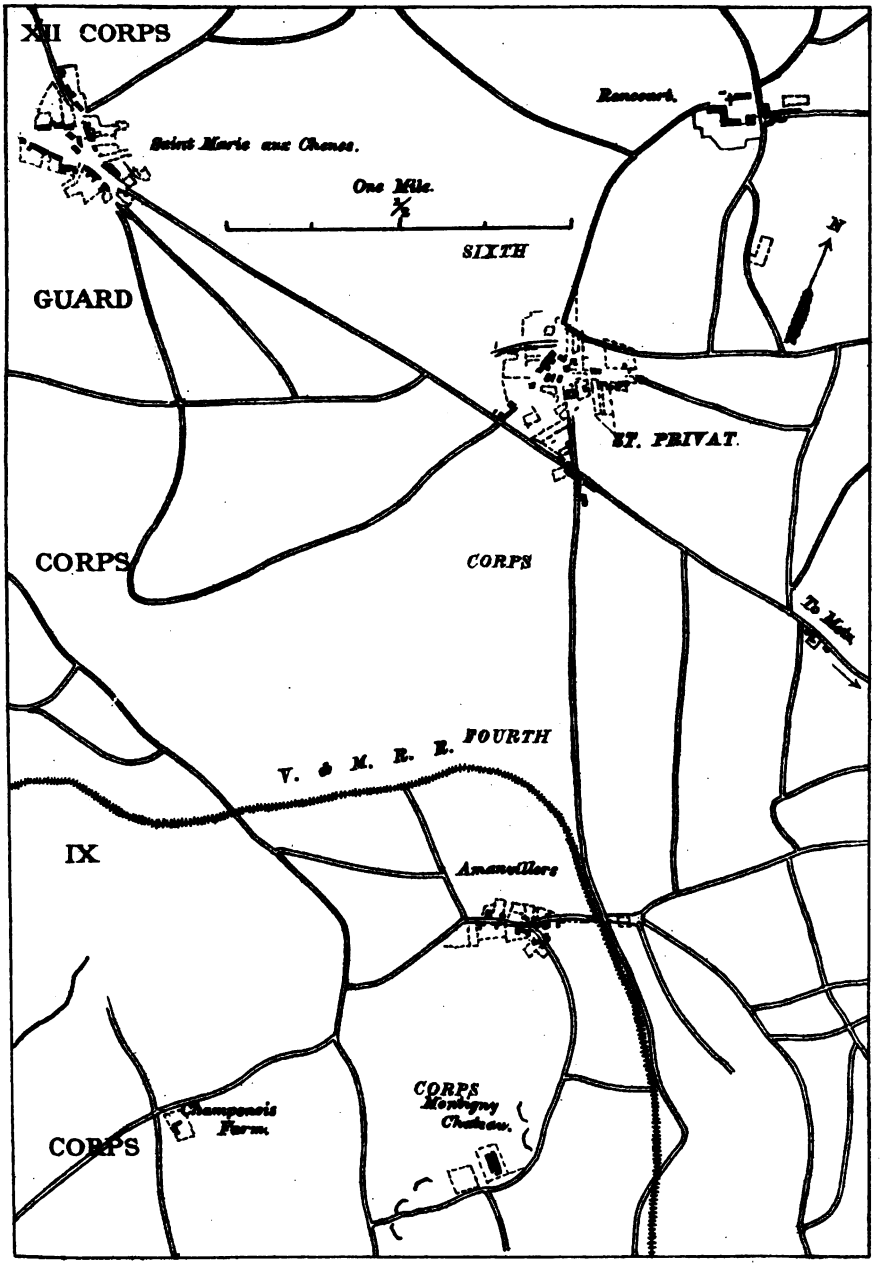
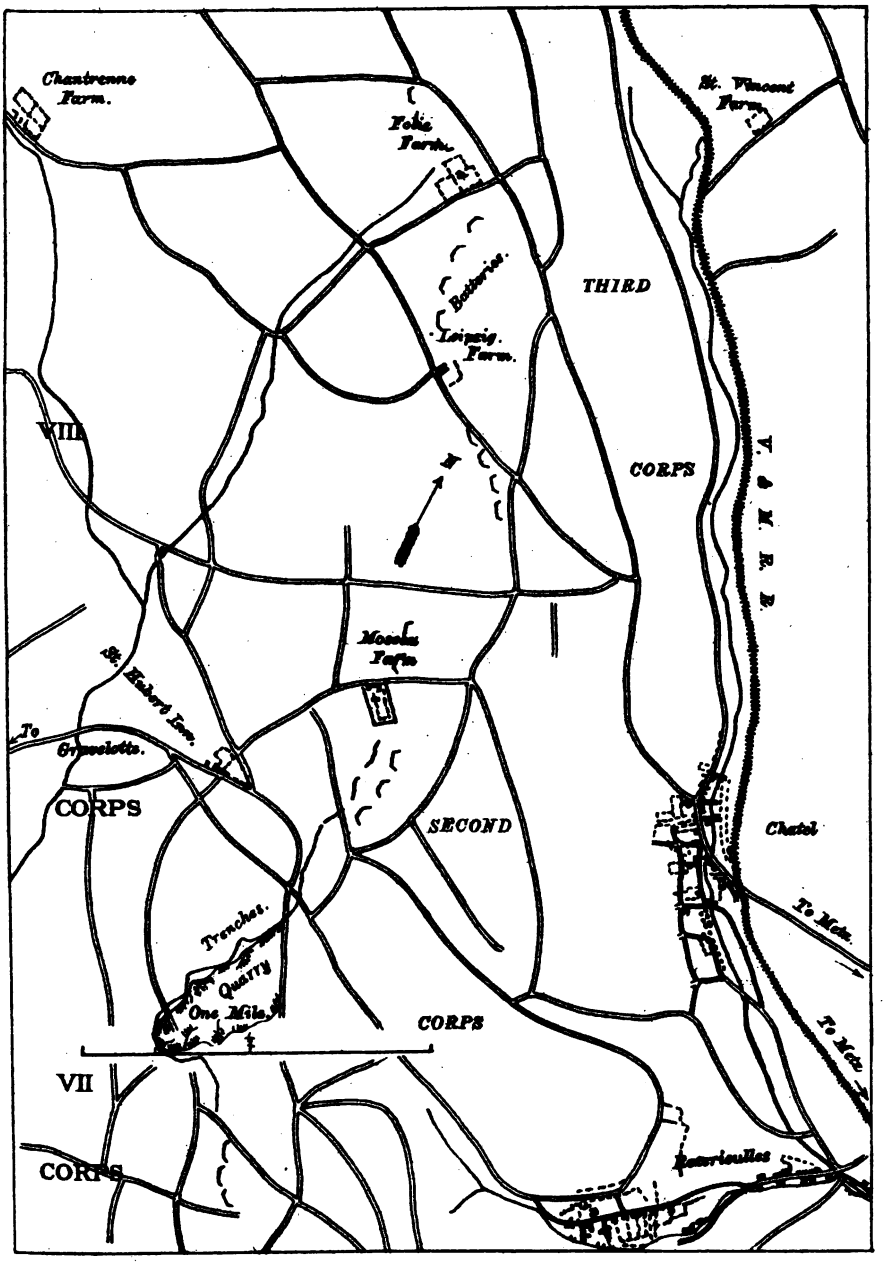


PLATE X.



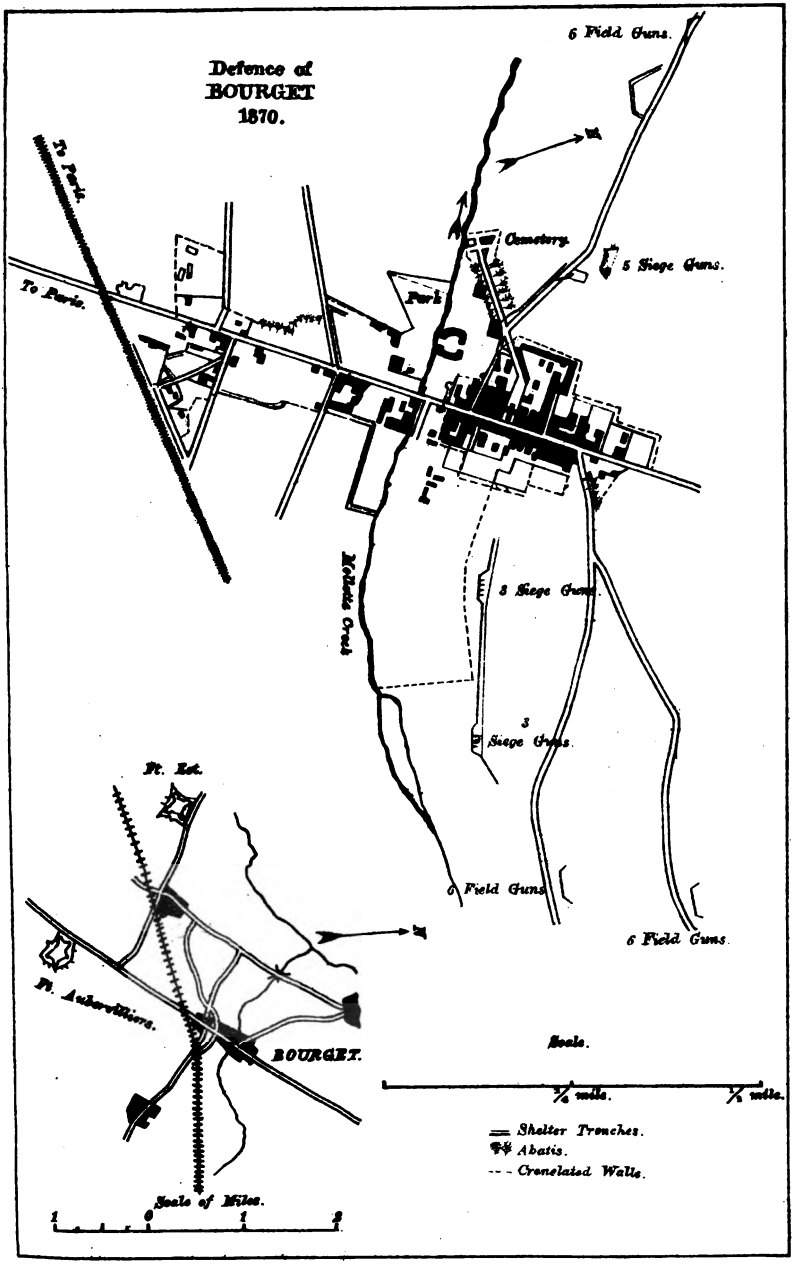
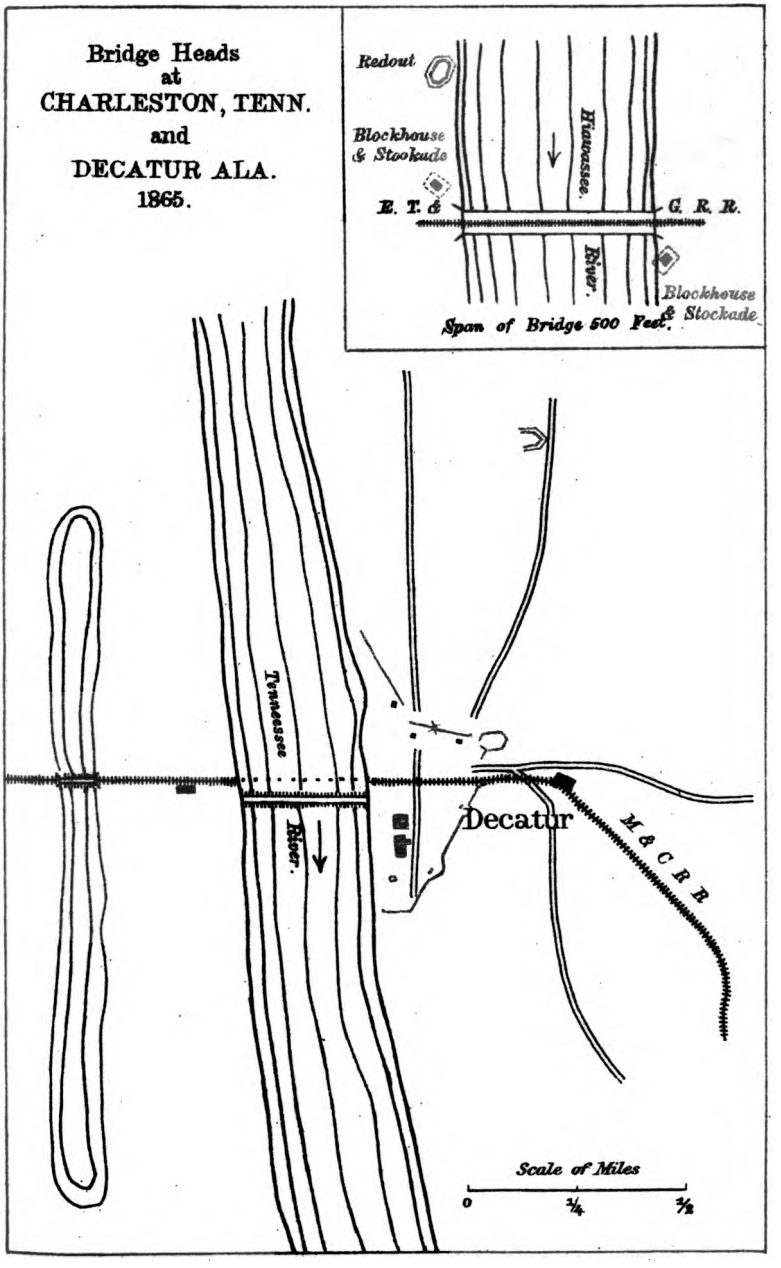


PLATE XII.



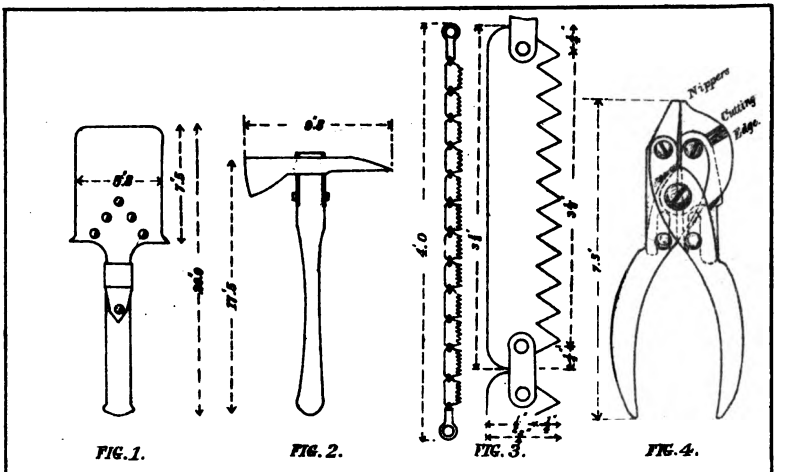
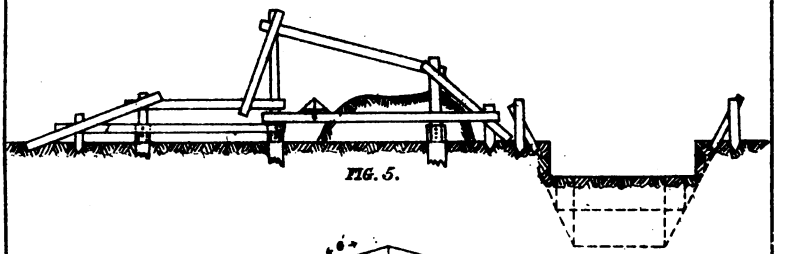


FIG. 1. FIG. 2. FIG. 3. FIG. 4.



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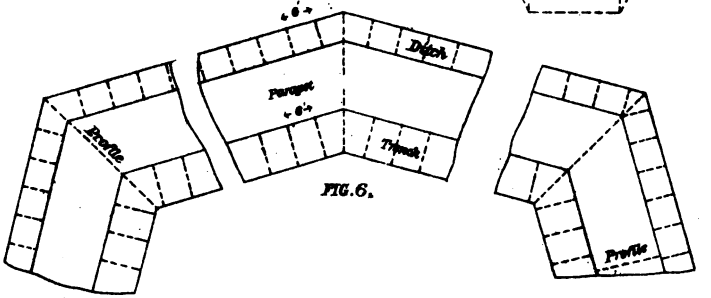


FIG. 6.

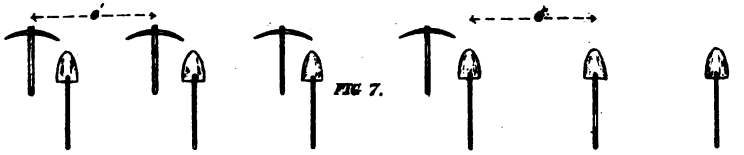


FIG. 7.

PLATE XIV.

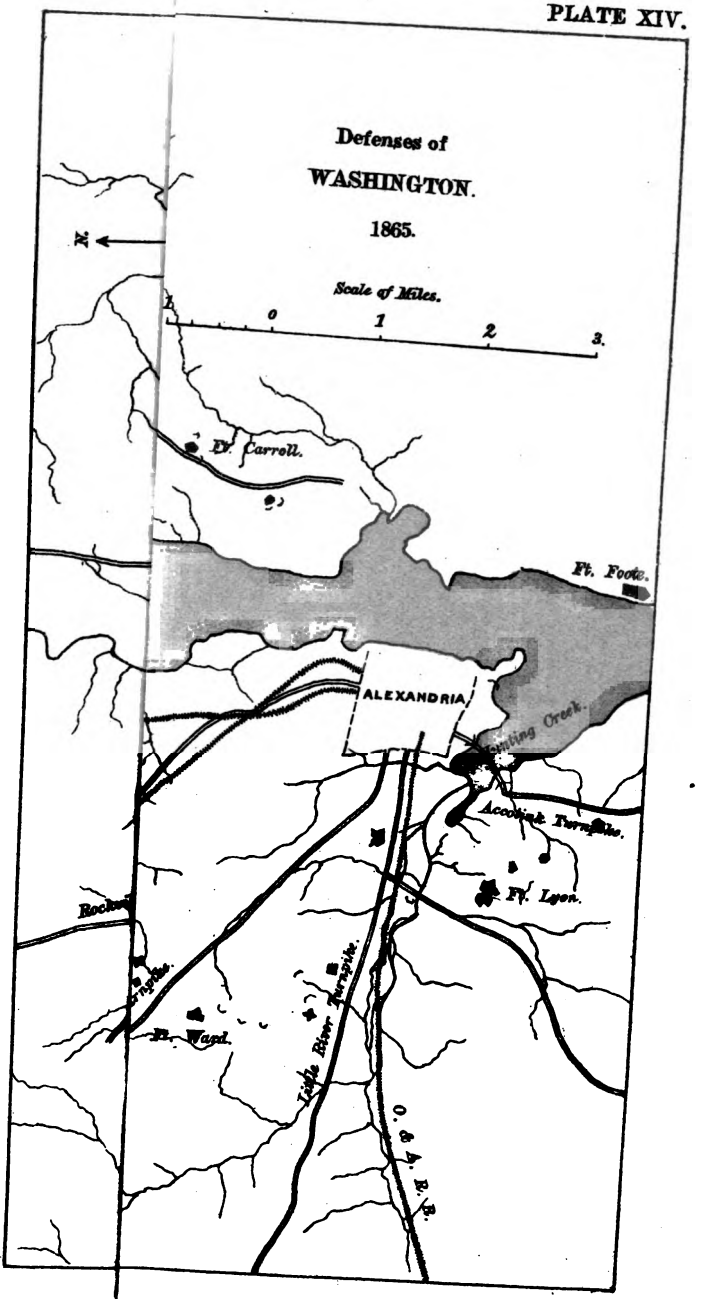
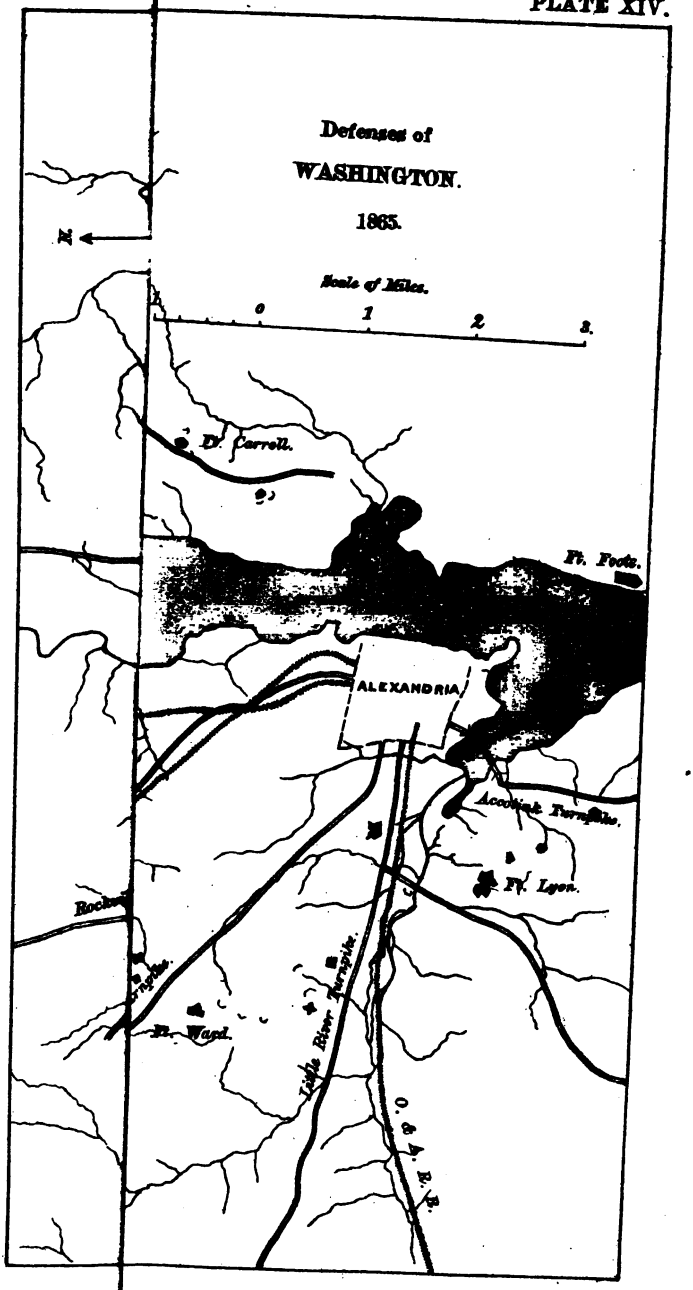
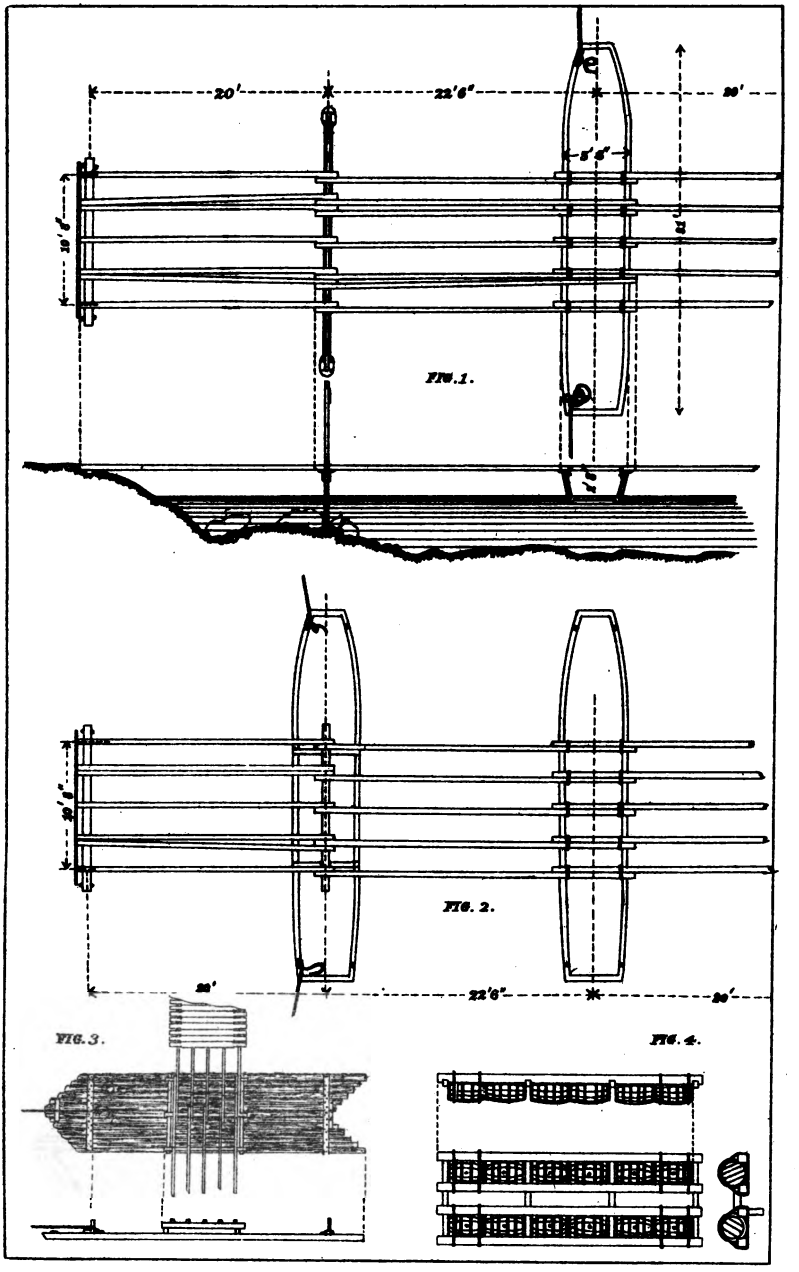


PLATE XIV.





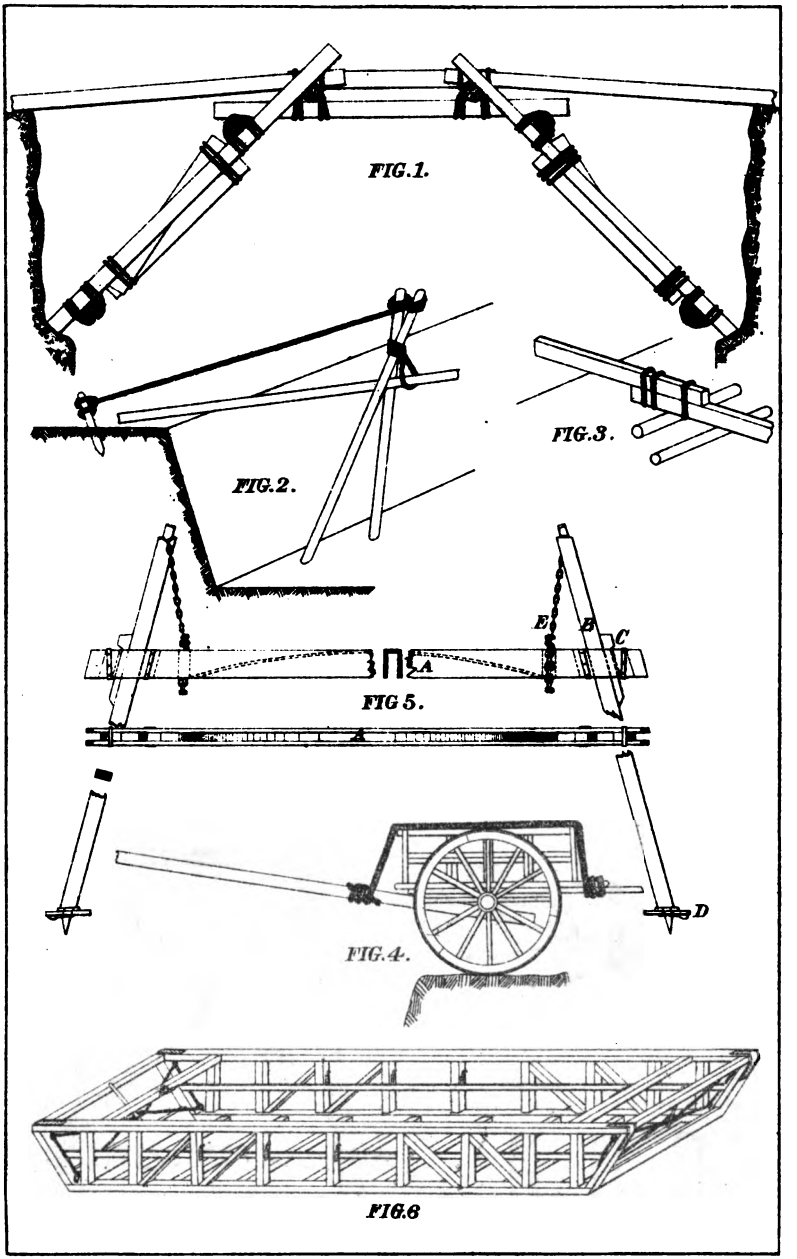


FIG. 1.

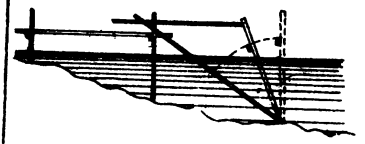
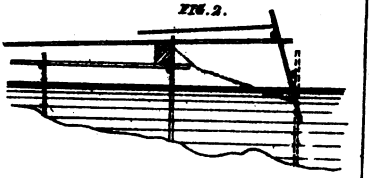


FIG. 2.



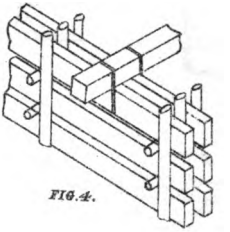
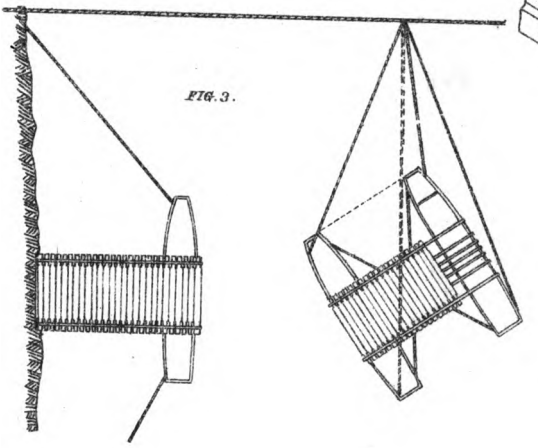


FIG. 4.

FIG. 3.



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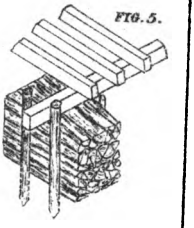

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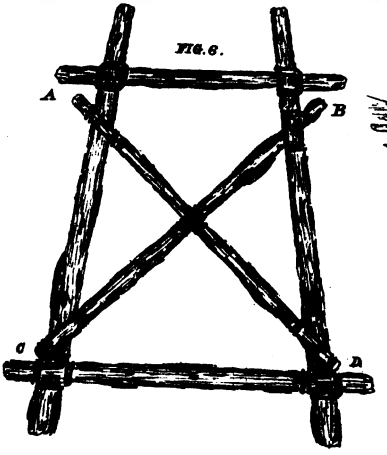


FIG. 7.

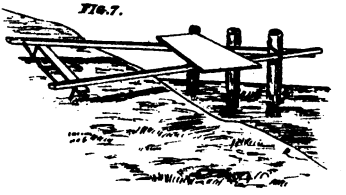


FIG. 8.

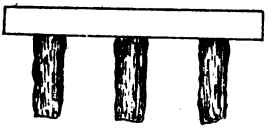
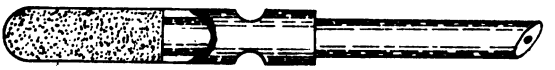


FIG. 1.



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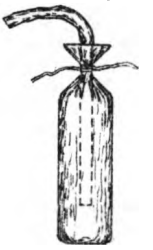
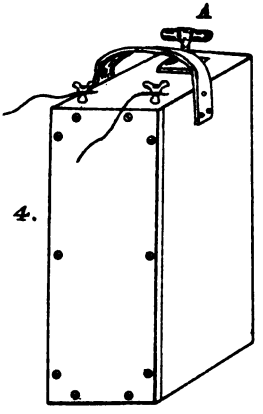


FIG. 3.

FIG. 4.



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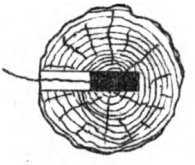

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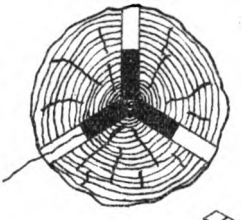

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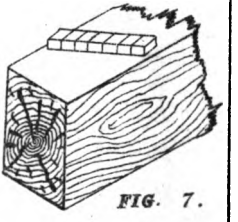
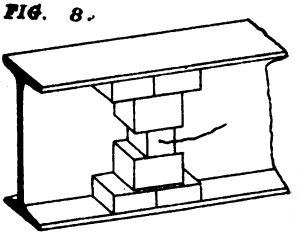


FIG. 8.



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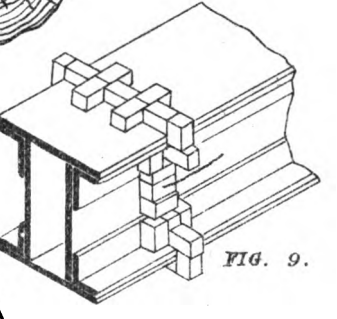

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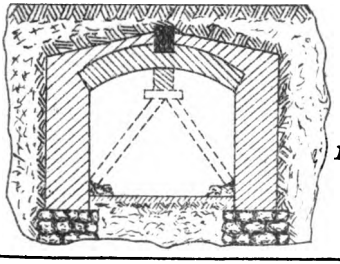

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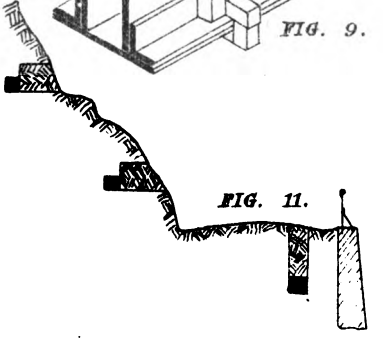


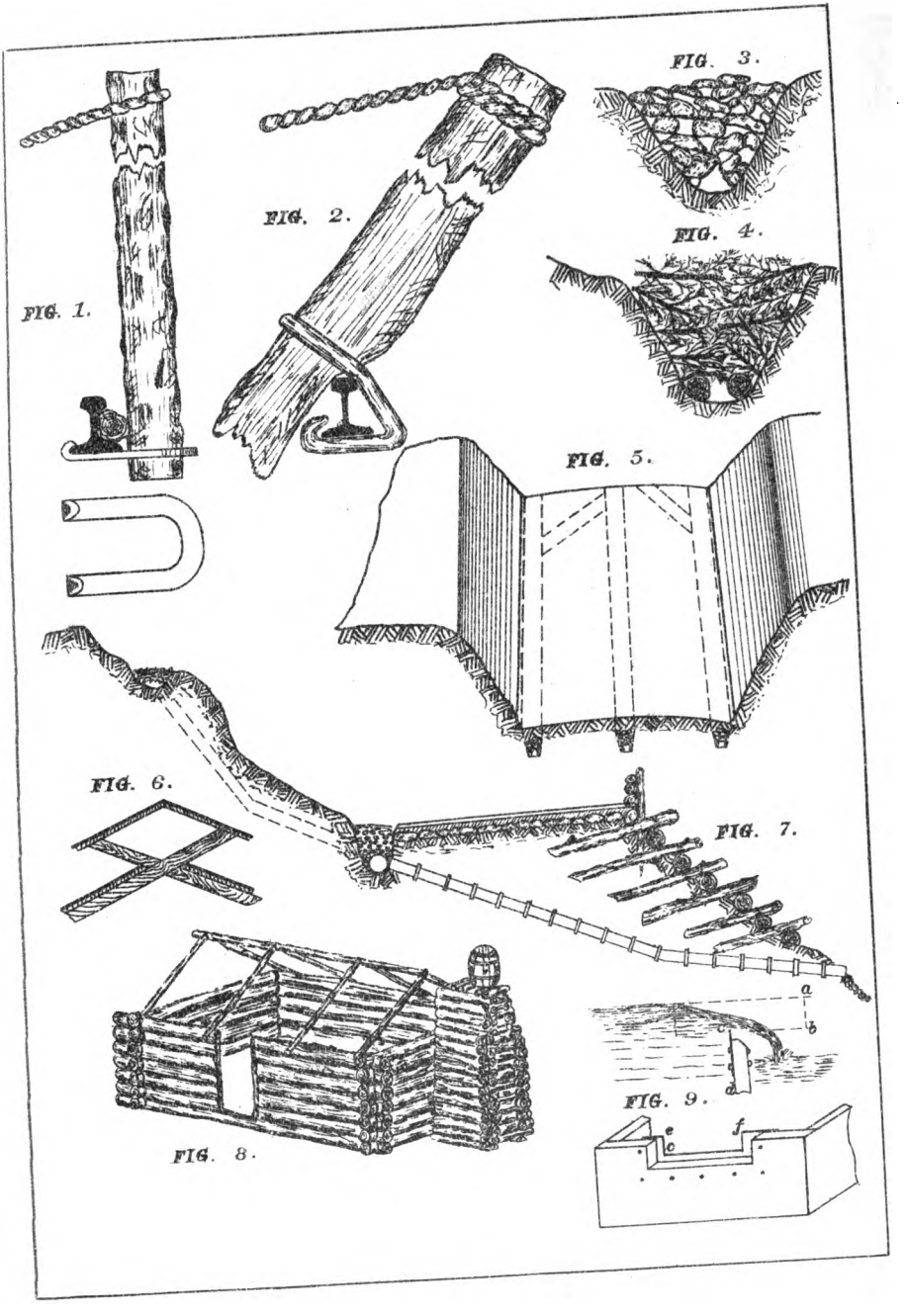
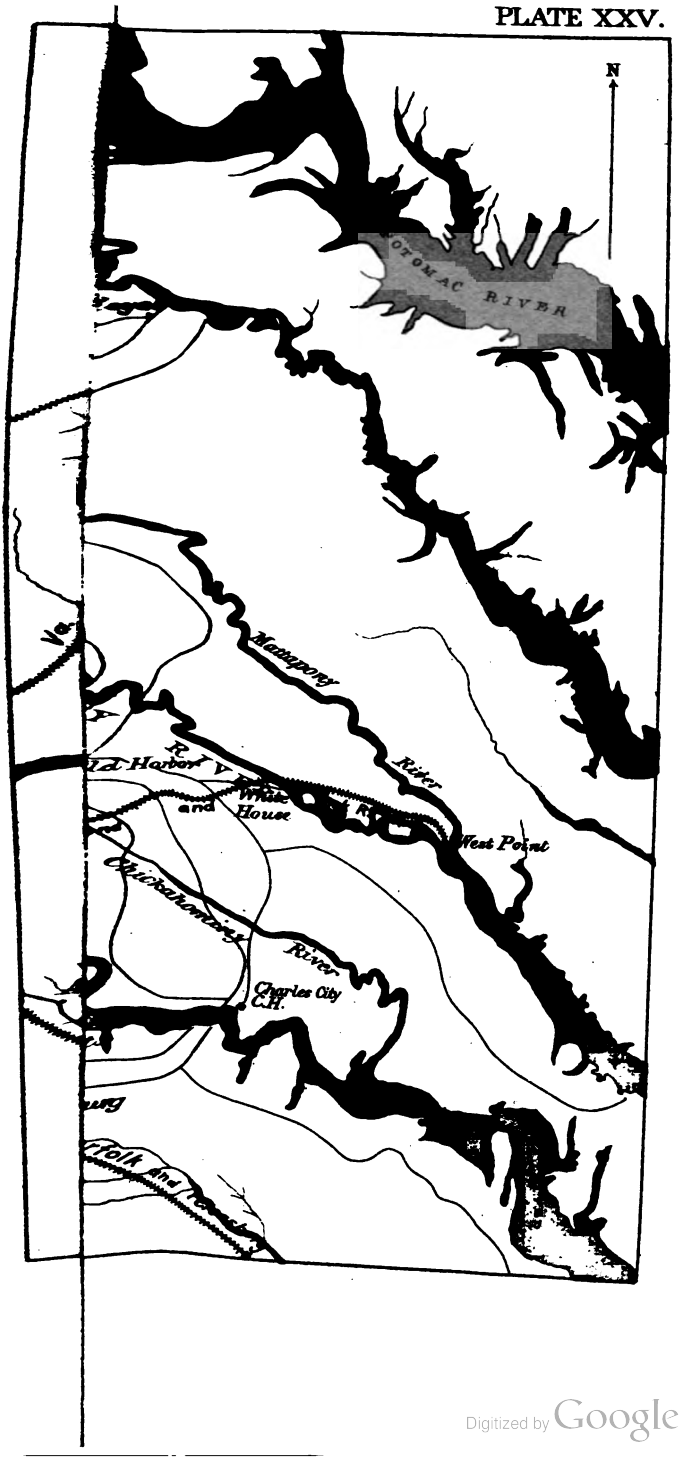


PLATE XXV.



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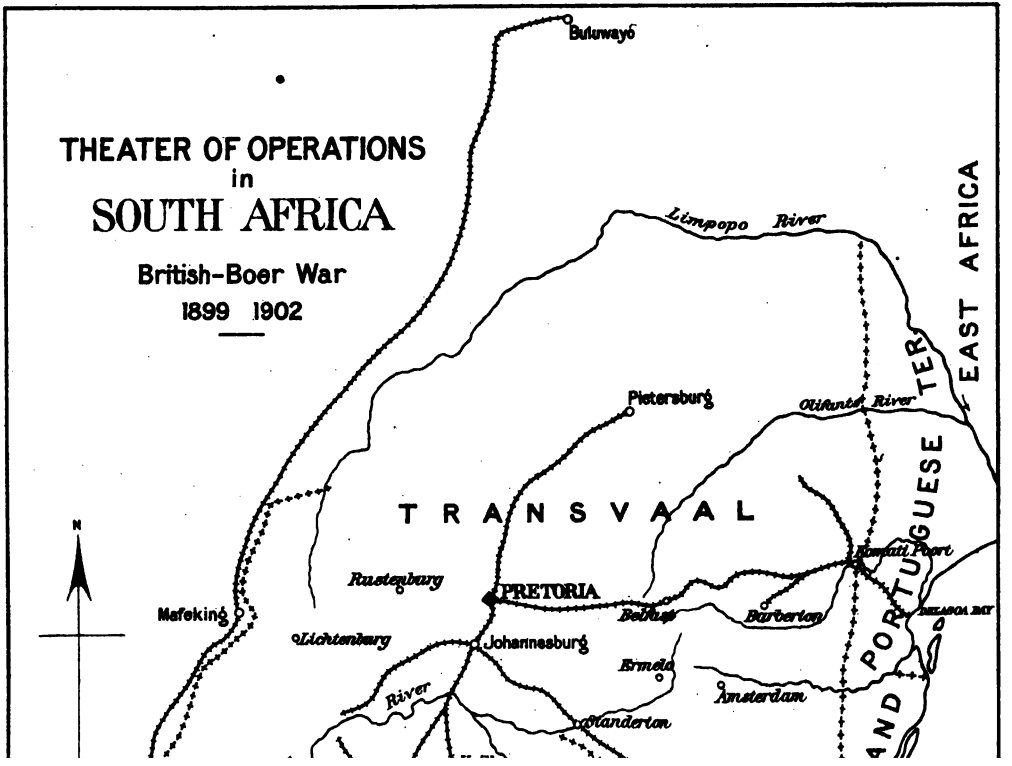
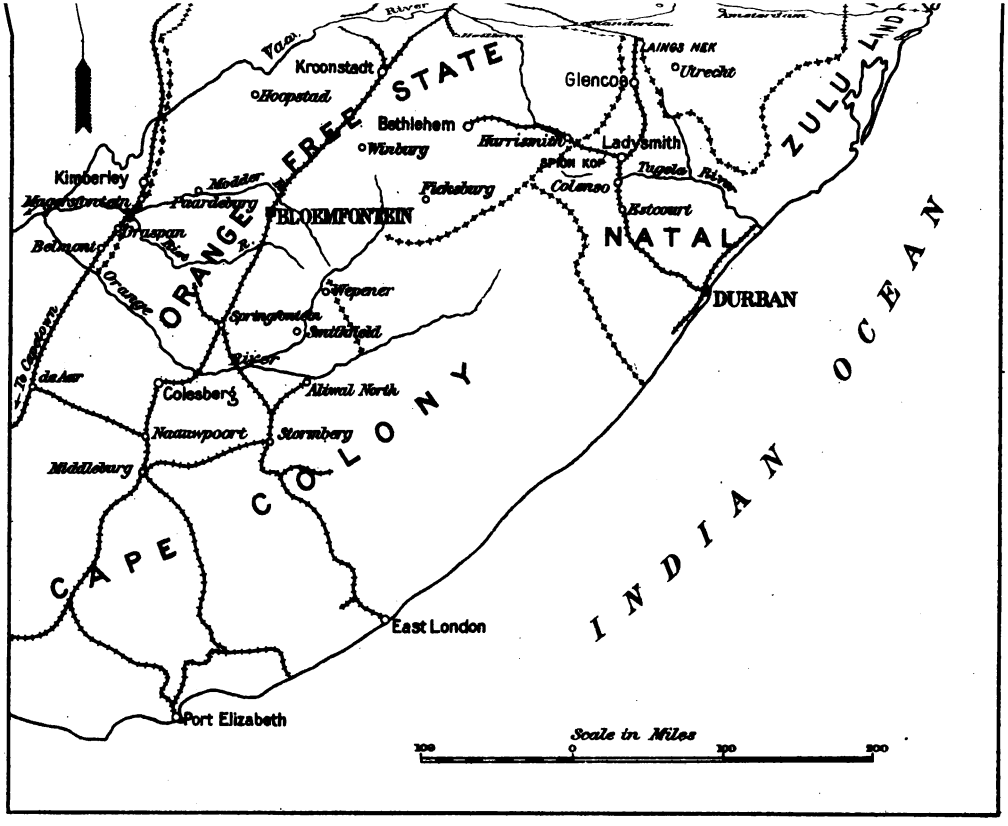




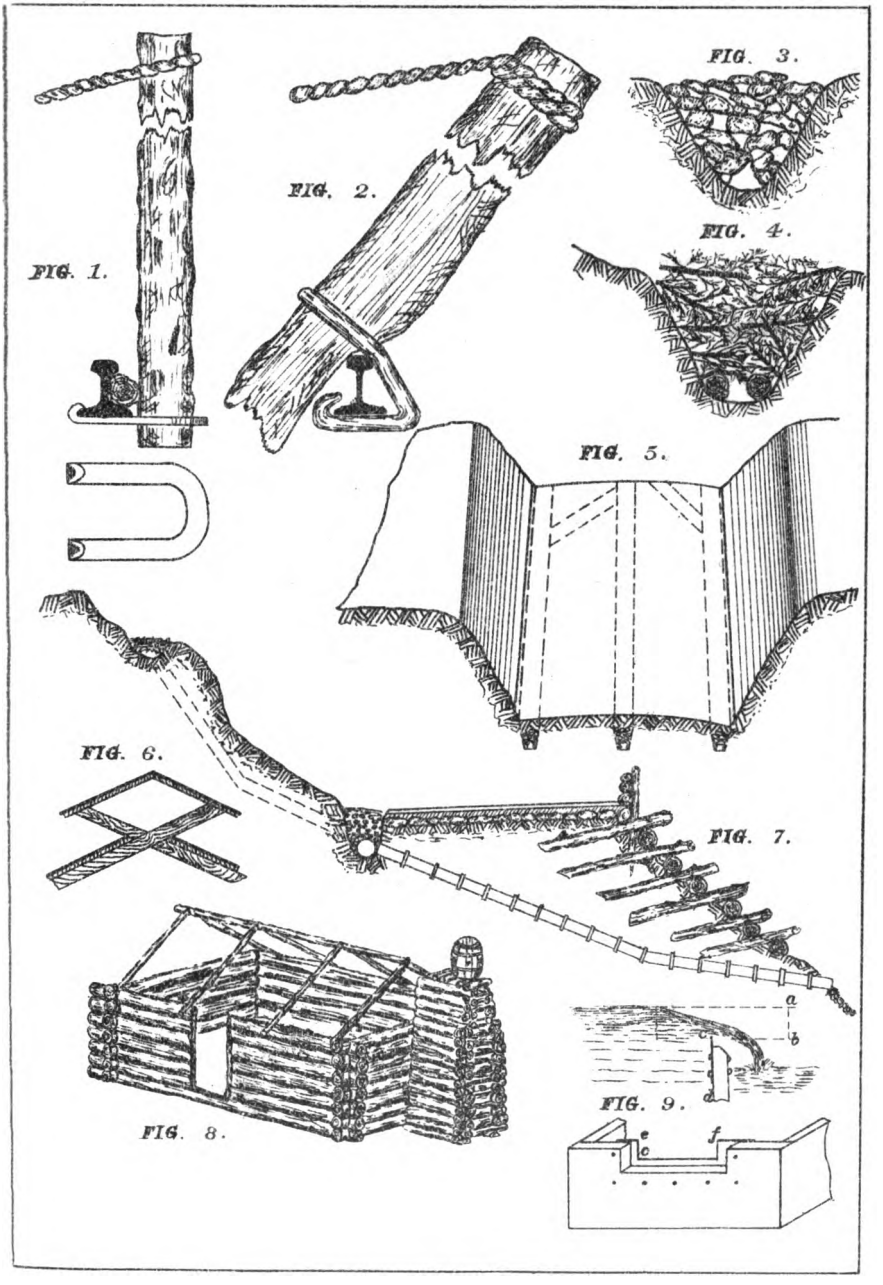


PLATE XXV.

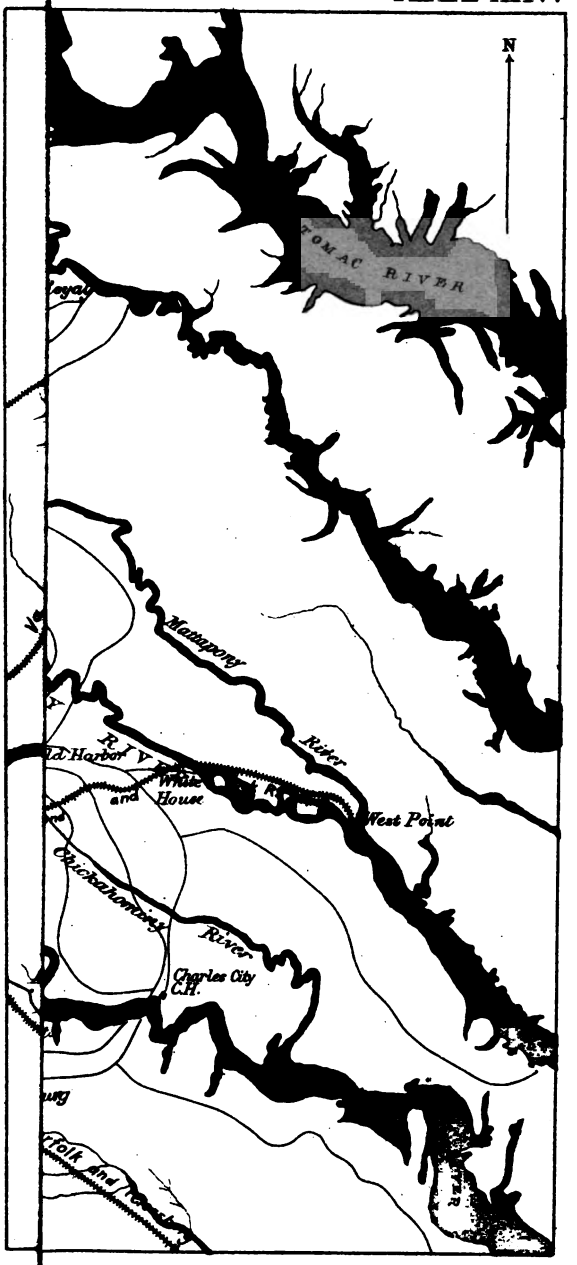
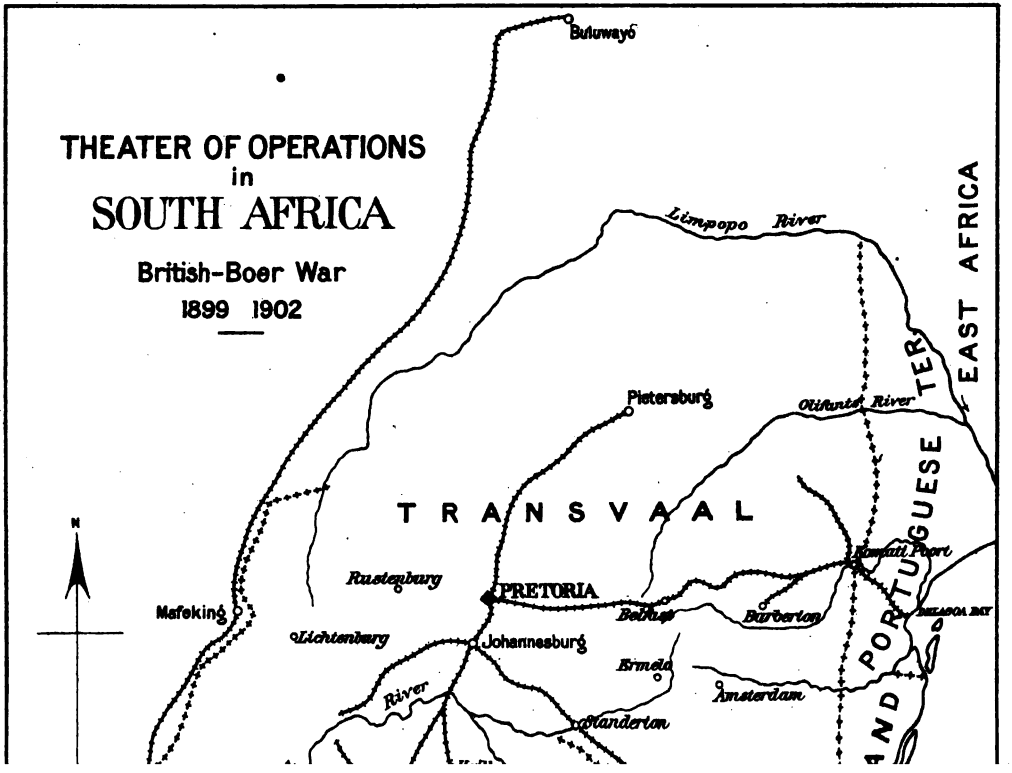


PLATE XXVI.



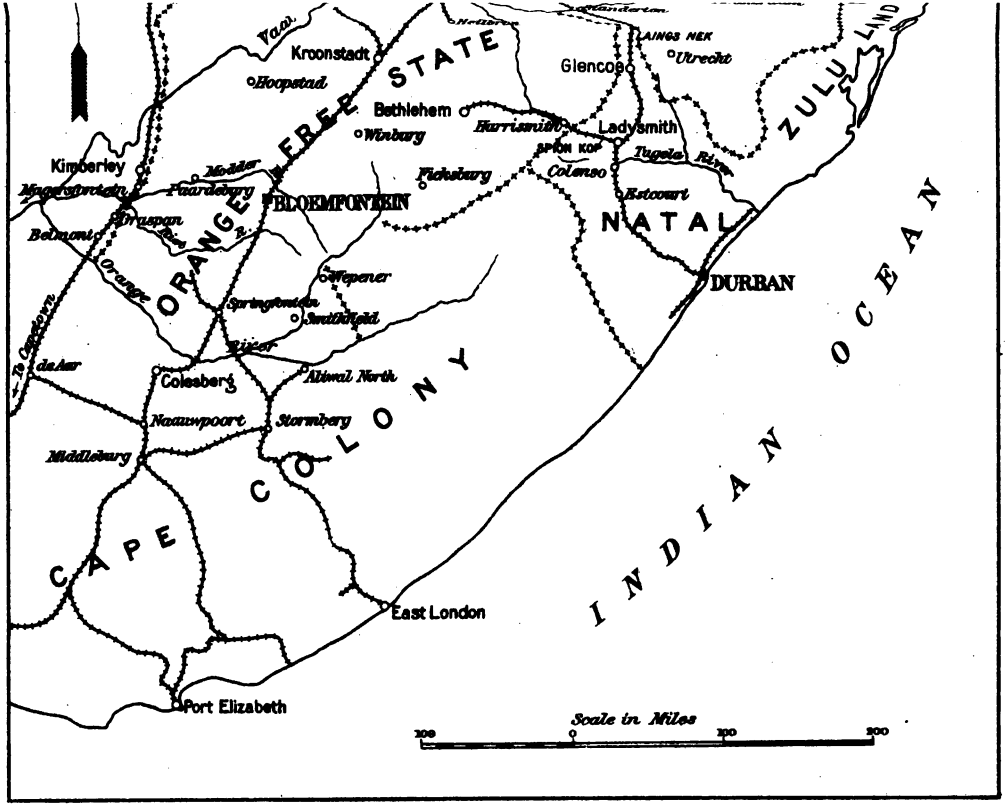


PLATE XXVII.